Appendix C Conceptual Models for Ecological System Conservation Elements

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Introduction

Ecological System Characterization and Conceptual Models

The conceptual models combine text, concept diagrams, and tabular summaries in order to state assumptions about the ecological composition, structure, dynamic processes, and interactions with major CAs within the ecoregion. These conceptual models lead then to spatial models to enable gauging the relative ecological status of each Conservation Element (CE), which will be completed in a later task of the REA. Below is described the content included for each CE. The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA; methods for selection are described in Harkness et al. (2013). The descriptive material builds upon the descriptions for terrestrial ecological systems that NatureServe has been compiling since 2003 when the ecological systems classification was first developed (see http://www.natureserve.org/explorer/index.htm to search and download existing descriptions). For this REA, additional material was added for each ecological system CE, especially focused on content describing natural and altered vegetation dynamics, as well as threats and stressors to the system. For the wetland/aquatic CEs, content was developed pertaining to the aquatic portion of the habitat: information pertaining to aquatic species, reproductive needs, as well as hydrologic needs (water temperature and chemistry) and in channel and within pond dynamics (water depths, rate of flow, interaction with groundwater and more). The information developed is generally intended to cover the full range of distribution of the CE, which can extend beyond the ecoregion, and but does focus on the characteristics or dynamics as they occur within this ecoregion.

The descriptions include many names of plant species that are characteristic of the ecological system type. In the text sections these names are provided as scientific names. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts. Where information is available, animal or plant species of conservation or management concern have been identified that are known to be strongly associated with the ecological system.

The list of ecological system CEs is provided in Table C-1, and each is placed within the broader conceptual model already established for the ecoregion (Harkness et al. 2013).

Table C-1. Ecological system conservation elements (ecosystems CEs) selected for the Madrean Archipelago REA; classification follows Comer et al. 2003.

Level 2 in ecoregional conceptual model	Ecosystem Name	Percent of Ecoregion
Valley Upland Ecosystems		**56.0%**
Desert Scrub	Chihuahuan Creosotebush Desert Scrub	13.2%
Semi-desert Shrub & Steppe	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	18.2%

Level 2 in ecoregional conceptual model	Ecosystem Name	Percent of Ecoregion
Foothill Woodlands	Madrean Encinal	5.1%
Connected Stream and Wetland Ecosystems		**4.5%**
Basin River & Riparian	North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream	3.3%
Marshes/Cienegas	North American Arid West Emergent Marsh/Cienega and Pond	1.0%
Montane Streams & Riparian	North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream	<1%
Isolated Wetland Ecosystem		**<1%**
Playa Lakes	North American Warm Desert Playa & Ephemeral Lake	<1%
Montane Upland Ecosystems		**13.4%**
Lower Montane Forests & Woodlands	Madrean Pinyon-Juniper Woodland	5.8%
Subalpine/Montane Forests & Woodlands	Madrean Montane Conifer-Oak Forest and Woodland (includes ponderosa pine)	2.8%
Montane Shrublands	Mogollon Chaparral	4.8%

One additional NatureServe ecological system was selected for assessment purposes, and a conceptual model has been developed for it: the Apacherian-Chihuahuan Mesquite Upland Scrub. From a mapping standpoint, this ecological system has been mapped as covering approximately 19.5% of the Madrean Archipelago ecoregion. However, it is a non-natural vegetation type comprised of a native woody species, mesquite, that has expanded its range and has become dominant in many area of the ecoregion. For the REA, it will be treated separately from the other ecosystem CEs, and its conceptual model is not provided in this appendix.

Conservation Element Characterization

This section of the conceptual model includes a narrative of the CE distribution, biophysical and hydrological setting, and floristic composition. For the wetland/aquatic CEs, the hydrologic regime and dynamics are also described.

The first section of the conceptual model deals with the classification used, the NatureServe terrestrial ecological systems, as described above. For each CE the NatureServe name and tracking code are provided; in some cases 2 or more ecological systems are conceptually combined into one CE for the MAR REA in which case all of those are listed. A second part of the classification section lists the ecological systems that are similar to those in the CE. Similarity might be due to floristic, structural or geographic overlap with the CE; in some cases similar ecological systems are listed because reviewers of the draft conceptual models expressed some confusion about the MAR CE in their comments.

For *upland* ecosystem CEs, a crosswalk to Ecological Site Descriptions (ESDs) applicable to the ecoregion is provided (https://esis.sc.egov.usda.gov/Welcome/pgESDWelcome.aspx). In general, crosswalks are provided only to approved ESDs by NRCS Multiple Resource Land Area (MLRA) that overlap the ecoregion; draft ESDs are being developed in New Mexico that crosswalk to some of these CEs, however because they are draft they are not included in the ESD crosswalk tables. The NRCS Site ID in the crosswalk table identifies each type as determined by NRCS. This list is not a complete cross-walk as some MLRAs do not have approved ESDs. Additionally, the user should consider that ESDs are based on landform/soil concepts, so the match between these concepts and ecological system concepts - defined as an integration between biophysical and natural floristic composition - will be imperfect and may vary from type to type.

The natural vegetation and ecosystem dynamics are described in narrative text, with supporting literature cited. For the upland ecosystem CEs, a diagrammatic representation of the natural dynamics is provided, either from one of the characteristic ESDs crosswalked to the ecological system (and hence a diagram from NRCS); or for some systems lacking ESDs, the natural dynamics diagram developed by The Nature Conservancy is presented and the source report cited. For the wetlands and aquatic CEs the diagrams were developed specifically for the MAR REA, and portray the structural components and functional relationships that characterize the ecosystem.

Species of Conservation or Management Concern Associated with Ecosystem

Some species of conservation or management concern are closely associated with these ecological system CEs. These species are of conservation or management concern due primarily to their relative vulnerability to extinction through alteration of this ecosystem. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects. Because of this strong association, the ecosystem type provides a practical way to “capture” or adequately represent these individual species and provide a reliable indication of the ecological status for each of these species. This is an approach, called “coarse filter / fine filter”, originally proposed by scientists from The Nature Conservancy (Jenkins 1976, Noss 1987) and has been used extensively in a variety of forms for regional and local landscape assessments (Nachlinger et al. 2001, Noss et al. 2002). For most of these species, the ecological system type serves as the focal resource for purposes of resource assessment. Although some of the species listed in this sub-section may be assessed individually (see separate conceptual models for them), most are listed to make users aware of associated species that are of concern.

The lists provided in the conceptual model were derived through consultation of State Wildlife Action Plans, or other sources, but are not definitively complete. Many reports list species of concern without providing information on related habitats or requirements. Time was not available to do detailed research on individual species in order to relate them to a MAR ecosystem CE. The sources for the list in each CM are provided. These species are listed by informal taxonomic groups, generally with common names followed by scientific names.

Change Agent Effects on the CE

In this section the primary change agents and current knowledge of their effects on the CE are characterized. Some CAs have specific effects on each CE such as the alteration of expected fire regimes and the interacting effects of introduced weed infestations. This section lists the known change agents and then moves into describing the altered ecosystem dynamics of the CE, with a narrative on the effects of CAs on the individual CE. Wildfire and invasive plant CAs are described and modeled within the context of their effects on upland ecosystem CEs. The altered dynamics section also contains a diagrammatic representation of the currently in-place ‘altered’ dynamics, again making use of either ESDs developed by NRCS, or TNC’s altered dynamics diagrams.

Diagrams for the Model

For uplands, the dynamics, either natural or altered, are generally represented by state-and-transition diagrams. States (boxes) represent a vegetation community defined by a cover type and structural stage. Transitions link states through processes such as succession, disturbance, and management, and can be either deterministic or probabilistic. Deterministic transitions usually simulate successional changes by defining the number of years until a transition occurs from one successional stage to the next, in the absence of disturbance. Probabilistic transitions specify an annual transition probability of moving from one state to another. Probabilistic transitions represent disturbances (e.g., fire and drought), ecological processes (e.g. tree encroachment and natural recovery), and land management activities (e.g., seeding and prescribed fire).

Each upland ecological system CE is represented by two diagrams – one describing the natural range of variation (NRV) under historic conditions, and one describing contemporary dynamics and including uncharacteristic states such as annual grass or depleted shrub. The contemporary model includes all states and transitions from the NRV model in addition to a set of uncharacteristic states and transitions.

For the wetlands and aquatic CEs the diagrams do not attempt to describe states and transitions; rather they portray the structural components and functional relationships that characterize the ecosystem. Two diagrams are provided: the first represents the key ecological attributes, ecosystem drivers, and the functional relationships between them, and a second diagram portrays the stressors and change agents that are currently acting upon the key attributes of the ecosystem.

Ecological Status: Key Ecological Attributes and Indicators

NatureServe's ecological integrity assessment framework identifies and outlines practical criteria for assessing the ecological status of each CE within an ecoregion (Faber-Langendoen et al. 2006, Unnasch et al. 2009). This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation. Is it within its "proper functioning condition"? Attributes are direct and indirect measures of ecosystem status or function. Key Ecological Attributes (or their indicators) should be measured to take the "pulse" of an ecosystem. High scores indicate high ecological integrity and high ecological functionality.

Key Ecological Attributes

The key ecological attributes for the CE within the Madrean Archipelago ecoregion are identified in this section. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance, e.g., resistance or resilience (Holling 1973, De Leo and Levin 1997, Parrish et al. 2003, Unnasch et al. 2009). Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less.

For each CE, a table provides identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Key ecological attributes of a resource include critical or dominant characteristics of the resource, such as specific characteristics of:

a) demographic or taxonomic composition;
b) functional composition;
c) spatial structure;

d) range or extent.

They also include critical biological and ecological processes and characteristics of the environment that:

a) limit the regional or local spatial distribution of the resource;
b) exert pivotal causal influence on other characteristics;
c) drive temporal variation in the resource's structure, composition, and distribution;
d) contribute significantly to the ability of the resource to resist change in the face of environmental disturbances or to recover following a disturbance; or
e) determine the sensitivity of the resource to human impacts.

Conservation of key ecological attributes contributes to current ecological integrity and to the resilience of ecological systems in the face of large-scale or long-term stressors (Parrish et al. 2003). The ecological integrity assessment framework (Unnasch et al. 2009) identifies four classes of key ecological attributes, concerning: landscape context; resource size or extent; biotic condition; and abiotic condition. These four may overlap, and provide a guide for considering and identifying key ecological attributes. They also provide a basis for integrating information on key ecological attributes.

- "Landscape context" refers both to the spatial structure (spatial patterning and connectivity) of the landscape within which the focal resource occurs; and to critical processes and environmental features that affect the focal ecological resource from beyond its immediate geographic scope.
- "Size" refers to the numerical size and/or geographic extent of a focal resource.
- "Biotic condition" refers to biological composition, reproduction and health, and succession; and critical ecological processes affecting biological structure, functional organization (e.g., food-web guild structure), and interactions.
- "Abiotic condition" refers to physical environmental features and dynamics within the geographic scope of the focal resource that significantly shape biotic conditions, such as fire, weather, and hydrologic regimes; and soil and geological conditions and dynamics.

Taken together these attributes tell the story of the current status of an ecosystem. For example, a good condition/proper functioning ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation: the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, amphibians, fish, or invertebrate species present are indicative of reference, un-molested conditions; the hydrologic or fire regime is within normal reference ranges, the highs and lows are within normal parameters, there are no excessive sediment loads or surface erosional processes, ecosystem geomorphology and soil are in proper form.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. very few native species expected for this ecosystem are present, or are in poor physical condition and are barely able to reproduce; birds, mammals, reptiles and amphibian species expected are not present or the ratio of species shows an imbalance of predator to prey populations, or have more opportunistic species and a lack of interior, poor competitor species (i.e. species guilds are not within the normal range of variation); abiotic condition is poor with high soil erosion, high sediment loads into water bodies, hill and gullies present, fire occurs too infrequently and much higher severity than acceptable resulting in changes to vegetation structure and composition.

Indicators of Key Attributes

Assessing the status of key ecological attributes requires explicit identification of indicators (also called metrics) – specific means for measuring their status. These are the detailed metrics that measure the amount or status of each key attribute. There are many potential indicators, and the choice is largely dependent on the purpose of the assessment and available data. An indicator may be a specific, measurable characteristic of the key ecological attribute; or a collection of such characteristics combined into a "multi-metric" index. Such indicators directly evaluate the condition of the KEAs and their responses to stressors (change agents).

Alternatively, indicators may evaluate the severity and extent of the stressors themselves. Such "Stressor" indicators may consist of a single measurement type, or a collection of such measurements combined into a multi-metric stressor index. Indicators of stressors are often used as indirect indicators of a key ecological attribute, because data on stressor condition is often far more readily available than data on direct indicators. Examples of stressor-based indicators include measures of overall landscape development such as the Landscape Condition Model methodology (Comer and Hak 2009, Comer and Faber-Langendoen 2013); measurements of invasive non-native annual grass distributions that affect fire regimes; or measurements of fragmentation due to development.

Once the REA for the MAR has moved into actual analysis and assessment of status, the indicators used for each KEA for each CE will be identified and explained in the CE conceptual models, along with results of the status assessment. For now, no indicators are listed.

References for the CE

Literature is listed that is relevant to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of the CE, in some cases from portions of it's range outside of the ecoregion. These are not exhaustive literature surveys, rather are an accumulation of known references. Some documents may be listed that are not cited in the narrative text.

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Upland Ecological System Conceptual Models

Valley Upland System

Desert Scrub

C-1 Chihuahuan Creosotebush Desert Scrub

C-1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Chihuahuan Creosotebush Desert Scrub (CES302.731)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan Mixed Desert and Thornscrub (CES302.734)
- Sonora-Mojave Creosotebush-White Bursage Desert Scrub (CES302.756); west edge of MAR
- Chihuahuan Mixed Desert and Thornscrub (CES302.734)
- Possibly degraded Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735)

C-1.2 Summary

This ecological system is the common lower elevation desert scrub that occurs throughout much of the Chihuahuan Desert and has recently expanded into former desert grasslands in the northern portion of its range. Stands typically occur in flat to gently sloping desert basins and on alluvial plains, extending up into lower to mid positions of piedmont slopes (bajada). Substrates range from coarse-textured loams on gravelly plains to finer-textured silty and clayey soils in basins. Soils are alluvial, typically loamy and non-saline, and frequently calcareous as they are often derived from limestone, and to a lesser degree igneous rocks. A pebbly desert pavement may be present on the soil surface (Figure C-1).

Figure C-1. Chihuahuan Creosotebush Desert Scrub on the east side of Dos Cabezas near Apache Pass (http://azfirescape.org).

Adjacent ecosystems may include Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735), Chihuahuan Mixed Desert and Thornscrub (CES302.734), Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733), and Madrean Juniper Savanna (CES305.730). Less commonly at upper elevations it may occur adjacent to Madrean Encinal (CES302.795) or Mogollon Chaparral (CES302.741) (Brown 1982b). The environmental description is based on several references, including Brown (1982b), Dick-Peddie (1993), Gibbens et al. (2005), Henrickson and Johnston (1986), Huerta-Martínez et al. (2004), MacMahon (1988), MacMahon and Wagner (1985), Muldavin et al. (2000b), Muldavin et al. (2002), and NatureServe Explorer (2013).

The vegetation is characterized by a moderate to sparse shrub layer (<10% cover on extremely xeric sites) that is typically strongly dominated by *Larrea tridentata* with *Flourensia cernua* often present to codominant (Figure C-1). A few scattered shrubs or succulents may also be present, such as *Agave lechuguilla, Parthenium incanum, Jatropha dioica, Koeberlinia spinosa, Lycium* spp., *Mortonia scabrella,* and *Yucca* spp. Additionally *Flourensia cernua* will often strongly dominate in silty basins that are included in this ecological system. In general, shrub diversity is low as this ecological system lacks codominant thornscrub and other mixed desert scrub species that are common on the gravelly mid to upper piedmont slopes. However, shrub diversity and cover may increase locally where soils are deeper and along minor drainages with occasional *Atriplex canescens, Gutierrezia sarothrae*, or *Prosopis* *glandulosa*. Herbaceous cover is usually low and composed of grasses, and some annual forbs. A cryptogamic soil crust is common in undisturbed stands. Common species may include *Bouteloua eriopoda, Dasyochloa pulchella (= Erioneuron pulchellum), Muhlenbergia porteri, Pleuraphis mutica, Scleropogon brevifolius*, and *Sporobolus airoides*. Included in this ecological system are *Larrea tridentata*-dominated shrublands with a sparse understory that occur on gravelly to silty, upper basin floors and alluvial plains. In some locations the invasive non-native *Pennisetum ciliare* (buffelgrass) may be abundant.

The vegetation description is based on several references, including Brown (1982b), Dick-Peddie (1993), Gibbens et al. (2005), Henrickson and Johnston (1986), Huerta-Martínez et al. (2004), MacMahon (1988), MacMahon and Wagner (1985), Muldavin et al. (2000b), Muldavin et al. (2002), and NatureServe Explorer (2013).

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-2. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table C-2. Chihuahuan Creosotebush Desert Scrub ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* (/ creosote bush / bush muhly)	R041XB 206AZ
041-Southeastern Arizona Basin and Range	Limy Slopes 8-12" p.z. / *Larrea tridentata - Acacia constricta / Muhlenbergia porteri – Aristida* (/ creosote bush - whitethorn acacia / bush muhly - threeawn)	R041XB 207AZ
041-Southeastern Arizona Basin and Range	Limy Upland 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri - Aristida* (/ creosote bush / bush muhly - threeawn)	R041XB 208AZ
041-Southeastern Arizona Basin and Range	Gypsum Upland 8-12" p.z. / *Larrea tridentata - Acacia constricta* / (/ creosotebush - whitethorn acacia /)/	R041XB 219AZ
041-Southeastern Arizona Basin and Range	Gypsum Slopes 8-12" p.z. / *Larrea tridentata - Acacia neovernicosa / Pleuraphis mutica – Aristida* (/ creosotebush - viscid acacia / tobosa - Aristida)	vR041X B231AZ
041-Southeastern Arizona Basin and Range	Limy Upland 12-16" p.z. / *Larrea tridentata - Acacia constricta / Muhlenbergia porteri – Aristida* (/ creosote bush - whitethorn acacia / bush muhly - threeawn)	R041XC 309AZ

C-1.3 Species of Conservation or Management Concern

Listed below are species of conservation or management concern that are associated with Creosotebush Scrub from the BLM Gila District (USDI-BLM 2010) and from TE/SOC/SOI Species Associations; Desert Communities from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009); and Species of Greatest Conservation Need (SGCN) from the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006).

Birds: Le Conte's Thrasher (*Toxostom lecontei*)

Reptiles: Gray-Checkered Whiptail (*Cnemidophorus dixoni*), Red-backed Whiptail (*Aspidoscelis xanthonota*)

C-1.4 Natural Dynamics

The Chihuahuan Creosotebush Desert Scrub CE is a stable ecosystem that is well suited to the hot, very dry basins and low hills where it occurs. The dominant and diagnostic species, *Larrea tridentata* is very long-lived species (some clones have been estimated to be over 10,000 years). It is highly adapted to minimized evapo-transpiration both daily and seasonally using stomatal regulation, resinous leaves, and a leaf structure and habit to minimize self-shading and maximize photosynthesis during favorable growing periods (Hamerlynck et al. 2002, Ogle and Reynolds 2002). *Larrea tridentata* is poorly adapted to fire because of its highly flammable, resinous leaves and limited sprouting ability after burning although it may survive lower intensity fires (Humphrey 1974, Brown and Minnich 1986, Marshall 1995, Paysen et al. 2000). McLaughlin and Bowers (1982) reported that burned individuals surviving a fire regained their former size in five years.

Historic fire regimes for Chihuahuan Creosotebush Desert Scrub are difficult to quantify but fires were rare with a fire return interval (FRI) ranging from 300-1000 years - 500 on average (from Landfire BpS Model 2510740). The fire characteristics range from low to moderate to high intensity, moderate severity, stand replacing crown fires that occur during spring, summer and fall seasons. Fires tend to be small or medium in size and need unusual conditions (e.g., a drought following an unusually wet year so there are adequate fine fuels are available to carry a fire) (Brown and Minnich 1986, Paysen et al. 2000).

Weather stress such as drought also affects this community by reducting vegetation cover (especially grasses) every 80 years or so, but does cause significant shrub mortality (from Landfire BpS Model 2510740) (Humphrey 1974).

Herbivory by native herbivores in the Chihuahuan Creosotebush Desert Scrub CE includes small mammals, reptiles and invertebrates. *Larrea* leaves are not edible to most animals; however seeds are used by many small mammals (Paysen et al. 2000).

A good condition/proper functioning Chihuahuan Creosotebush Desert Scrub is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation: the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 300-1000 years, soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or disturbed by off road vehicles; the biotic condition is at the limit or beyond natural range of variation, e.g. vegetation composition is altered and is not dominated by native shrubs such as *Larrea tridentata* and *Flourensia cernua.* Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons. Non-native grasses invasion provides fine fuels that may increase fire frequency, intensity and severity.

C-1.4.1 Natural Dynamics Model

Conceptual historic state-and-transition models were developed by several ecology teams (Schussman 2006, Muldavin et al. 2012, and NRCS) for the Chihuahuan Creosotebush Desert Scrub ecosystem. Below is a conceptual historic state and transition model of the Historic Climax Plant Community (HCPC) portion of the state and transition model for Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia* *porteri* ESD R041XA107AZ from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Chihuahuan Creosotebush Desert Scrub (Figure C-2).

Figure C-2. Conceptual state and transition model of historic conditions for the Chihuahuan Creosotebush Desert Scrub CE.. This model is the Historic Climax Plant Community (HCPC) portion of a larger model from NRCS ESD R041XB206AZ Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri*.

From ESD R041XB206AZ:

<u>Description of State and Transition Model</u>

The following model discussion is excerpted from the Ecological Site Description (ESD) for R041XB206AZ. Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA. https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD

"The potential plant community is a shrub-land dominated by creosotebush. Annual forbs and grasses are very important in the plant community on this site. Cryptogams (lichens, mosses) and blue-green algae are also important in the plant communities on this site. With continuous heavy grazing, bush muhly is removed from the plant community and creosotebush increases. Areas of this site mapped in alluvial fan positions are very susceptible to rill and gully erosion."

C-1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Chihuahuan Creosotebush Desert Scrub ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-1.5.1 List of Primary Change Agents

Occurrences of this desert scrub ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression activities, land development, and non-native plant species invasion. Table C-3 identifies the most likely impacts associated with each of these stressors.

Table C-3. Stressors and their likely impacts on the Chihuahuan Creosotebush Desert Scrub ecosystem CE in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Although limited in extent in desert scrub, grazing by livestock (inappropriate stocking rates, season of use, or duration) can affect the structure and composition of desert plant communities, as well as soil structure and water infiltration (Milchunas 2006). Livestock movement can be a vector for invasive non-native plant seed (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes such as surface flow when excessive runoff from roads creates gullies. Additionally increased mortality from road kill affects wildlife (USDA-USFS 2009).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Uncharacteristic Fire Regime	Fire is not a natural disturbance process in desert communities. Fire kills many native desert plants. No native desert species of conservation concern are adapted to fire (USDA-USFS 2009).
Invasive non-native Species	Invasive non-native grasses out-compete and replace native desert plants. These grasses burn easily, and so fire frequency and severity increases. Invasive non-native grasses fill gaps needed by some species, reduce available native foods, and shift prey species assemblages. Species diversity suffers (USDA-USFS 2009).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.

C-1.5.2 Altered Dynamics

Altered dynamics are not an issue with historic stands of Chihuahuan Creosotebush Desert Scrub as it is a stable vegetation type with robust ecological dynamics, although it can be sensitive to anthropogenic disturbance such as mechanical/chemical removal. However, in the U.S., much of the current extent of this desert scrub is the result of recent expansion of *Larrea tridentata* into former desert grasslands in the last 150 years from the combined effects of drought, overgrazing by livestock, and/or decreases in fire frequency over the last 70-250 years (Buffington and Herbel 1965, Ahlstrand 1979, Donart 1984, Dick-Peddie 1993, Gibbens et al. 2005). This system now includes vast areas of loamy plains that have been converted from *Pleuraphis mutica* and *Bouteloua eriopoda* desert grasslands to *Larrea tridentata* scrub. This system also includes expanding *Flourensia cernua* shrublands that occur in former (now degraded) tobosa (*Pleuraphis mutica*) flats and loamy plains. Presence of *Scleropogon brevifolius* is common on these degraded sites. Dick-Peddie (1993) suggested that absence of *Flourensia cernua* as codominant and presence of *Dasyochloa pulchella, Acourtia nana (= Perezia nana)*, and *Yucca elata* may be indicators of recent conversion of desert grasslands into desert scrub, but more research is needed. Conversely, *Larrea tridentata* shrublands with a sparse understory on remnant early Holocene erosional surfaces (often with desert pavement), may indicate historic distributions of *Larrea tridentata* desert scrub in the Chihuahuan Desert (Muldavin et al. 2000b).

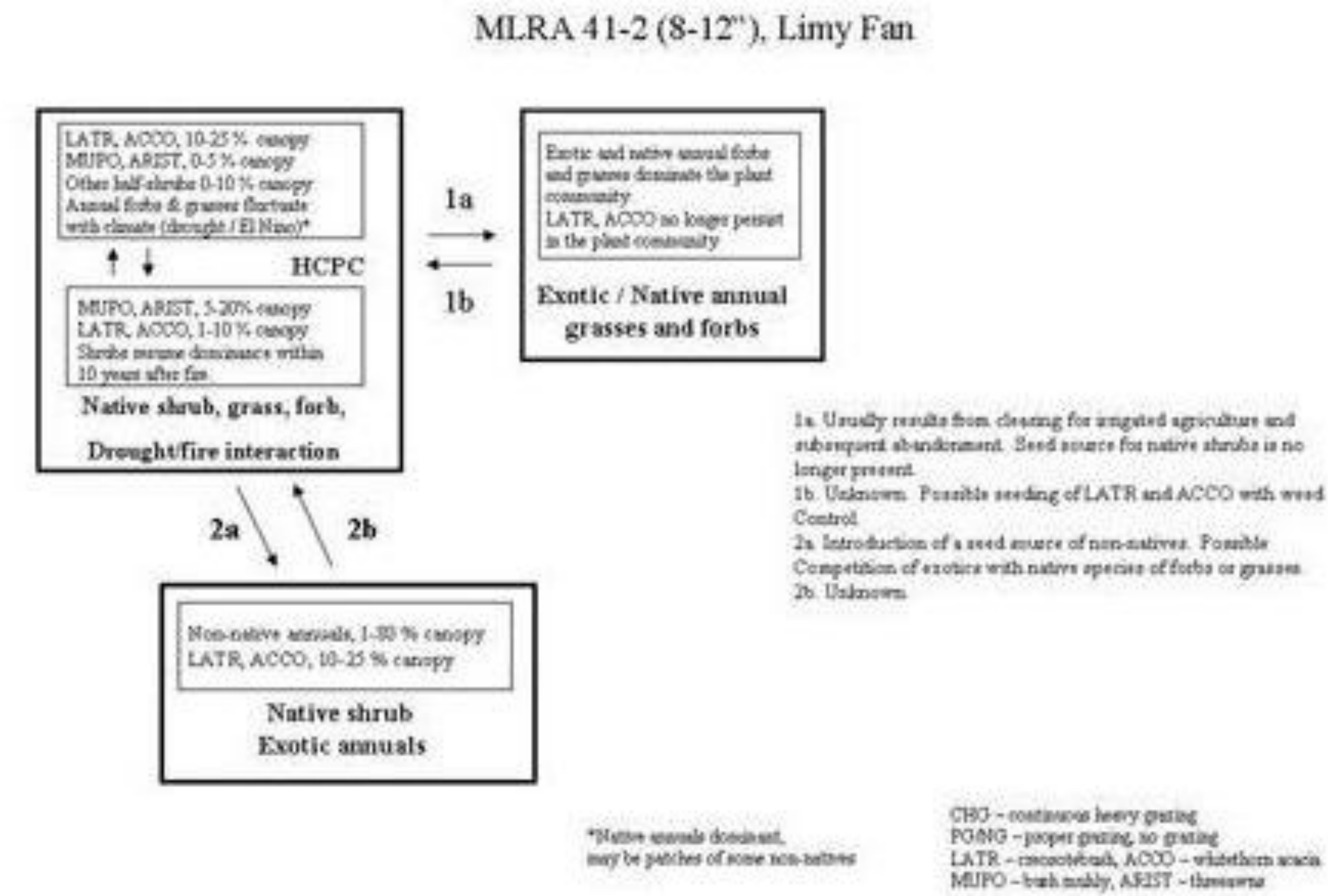
The impact of livestock grazing to the historic stands of desert scrub is expected to be relatively small because there is little forage available for them in this type, but where livestock grazing or other anthropomorphic disturbance occurs there may be increased soil erosion.

Altered (uncharacteristic) fire regimes greatly influence ecosystem processes. The historic desert scrub has a very long fire return interval (FRI) ranging from 300-1000 years (500 years on average) (from Landfire BpS Model 2510740). *Larrea tridentata* and other desert scrub plant species are sensitive to burning, most do not resprout and are slow to recover, and therefore burning should be a rare event to be avoided. Invasion of non-native grasses provides fine fuels that may increase fire frequency, intensity and severity.

C-1.5.3 Altered Dynamics Model

Conceptual state-and-transition models were developed by several ecology teams (Schussman 2006), Muldavin et al. 2012, and NRCS) for the Chihuahuan Creosotebush Desert Scrub ecosystem. Below is a conceptual state and transition model of the current conditions for the NRCS ESD R041XB206AZ for Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Chihuahuan Creosotebush Desert Scrub (Figure C-3). It includes the Historic Climax Plant Community (HCPC) as part of the model.

Figure C-3. Conceptual state and transition model of current conditions for the Chihuahuan Creosotebush Desert Scrub CE. This model is from NRCS ESD R041XB206AZ Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



From ESD R041XB206AZ:

Description of State and Transition Model

The following model discussion is excerpted from Ecological Site Description (ESD) for R041XB206AZ. Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA. https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrows indicating introduction of non-native annual grasses and forbs. The following model discussion is excerpted from Ecological Site Description (ESD) for R041XB206AZ Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA.

“The potential plant community is a shrub-land dominated by creosotebush. Annual forbs and grasses are very important in the plant community on this site. Cryptogams (lichens, mosses) and blue-green algae are also important in the plant communities on this site. With continuous heavy grazing, bush muhly is removed from the plant community and creosotebush increases. Areas of this site mapped in alluvial fan positions are very susceptible to rill and gully erosion.”

C-1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-1.6.1 Key Ecological Attributes

Table C-4 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource’s biology, ecology, or physical environment that is critical to the resource’s persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-4. Key Ecological Attributes (KEA) used to determine the ecological status of Chihuahuan Creosotebush Desert Scrub ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Matrix/Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres) for large patch to 2000 to 405,000 hectares (approximately 5000 to 1,000,000 acres) for matrix.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). Invasive non-native grasses may out-compete and replace native desert plants. These grasses burn easily, and so fire frequency and severity increases (USDA-USFS 2009). Livestock grazing can affect the structure and composition of some desert scrub, as well as soil structure and water infiltration, and species diversity. Plant species vary in their sensitivity to different stresses such as livestock grazing or fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open canopy of shrubs with low cover of grass vegetation is typical of the Chihuahuan Creosotebush Desert Scrub CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.

KEA Class: Name	Definition general	Rationale general	Stressors general
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. For Chihuahuan Creosotebush Desert Scrub fire return interval (FRI) is very long ranging from 300-1000 years (500 years on average) (from Landfire BpS Model 2510740). The fire intensity varies from low to high intensity, moderate severity stand replacing crown fires that occur during spring, summer and fall seasons. Fires tend to be small or medium in size and need unusual conditions to burn. Increased fire frequency is detrimental to this ecosystem.	Fire in fire-sensitive ecosystems results in decreased woody species density and cover, changes in wildlife species assemblages, and often increased fine fuels that increase frequency of fire.

C-1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table C-4 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-5. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-5. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table C-5. Key Ecological Attributes (KEA) for the Chihuahuan Creosotebush Desert Scrub ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-1.8 Conceptual Model Diagrams

See Figure C-2 and Figure C-3 above.

C-1.9 References for the CE

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Semi-desert Shrub & Steppe

C-2 Apacherian-Chihuahuan Semi-Desert Grassland and Steppe

C-2.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan Loamy Plains Desert Grassland (CES302.061) – upland tobosa - grama
- Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736) – black grama
- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)

This CE is the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, which is the same as the mixed semi-desert grassland in Schussman (2006). The other grasslands mentioned are not included in this CE. Similar grasslands include the *Pleuraphis mutica*-dominated semi-desert grasslands often with *Bouteloua eriopoda* or *Bouteloua gracilis* occurring on lowlands and loamy plains in the Chihuahuan Desert (Chihuahuan Loamy Plains Desert Grassland, CES302.061) and the *Bouteloua eriopoda* or *Sporobolus flexuosus* dominated grasslands associated with sandy soils which are classified as Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736). Neither of these are included in this CE.

C-2.2 Summary

This ecosystem is a broadly defined desert grassland and mixed shrub-succulent type that is typical of the Borderlands of Arizona, New Mexico and northern Mexico (Apacherian region) but extends west to the Sonoran Desert, north into the Mogollon Rim in central Arizona and east into Trans Pecos or West Texas and throughout much of the Chihuahuan Desert. It is found on gently sloping alluvial erosional fans and piedmonts (bajadas) that lie along mountain fronts of the isolated basin ranges throughout the Sky Island mountain archipelago and on to foothill slopes up to 1670 m elevation in the Chihuahuan Desert (Figure C-4).

Adjacent ecological systems may include Madrean Juniper Savanna (CES305.730), Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Encinal (CES305.795) at higher elevations and Chihuahuan Mixed Desert and Thornscrub (CES302.734) and Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733) at lower elevations. Substrates are a mixture of alluvium and colluvium and are variable, ranging from silt to loam to coarse sand, and are often shallow, well-drained and rocky. The environmental description is based on several references, including Brown (1982), Burgess (1995), Dick-Peddie (1993), McAuliffe (1995), Muldavin et al. (2000b), Schussman (2006), and NatureServe Explorer (2011).

Figure C-4. Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (http://azfirescape.org).

The vegetation in this mixed semi-desert grassland ecosystem is variable. It is characterized by the dominance of a typically diverse layer of perennial grasses with scattered stem succulents and shrubs. Frequent species include the grasses *Aristida ternipes, Bouteloua chondrosioides, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Bouteloua hirsuta, Bouteloua ramosa, Bouteloua repens, Bouteloua rothrockii, Digitaria californica, Eragrostis intermedia, Heteropogon contortus, Hilaria belangeri, Leptochloa dubia, Muhlenbergia porteri,* with *Muhlenbergia emersleyi, Muhlenbergia setifolia* at upper foothill elevation, succulent species of *Agave, Dasylirion, Nolina, Opuntia*, and *Yucca*, and short-shrub species of *Calliandra, Mimosa*, and *Parthenium*. Tall-shrub/short-tree species of *Acacia, Prosopis*, *Juniperus*, and various oaks (e.g. *Quercus grisea, Quercus emoryi, Quercus arizonica, Quercus oblongifolia*) may be present with low cover.

Similar grasslands include the *Pleuraphis mutica*-dominated semi-desert grasslands often with *Bouteloua eriopoda* or *Bouteloua gracilis* occurring on lowlands and loamy plains in the Chihuahuan Desert are classified as Chihuahuan Loamy Plains Desert Grassland (CES302.061) and the *Bouteloua eriopoda* or *Sporobolus flexuosus* dominated grasslands associated with sandy soils which are classified as Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736). These other grasslands systems are not included in this mixed semi-desert grassland CE.

Many of the historical semi-desert grassland and savanna areas have been converted through intensive grazing and other land uses, some to Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733)

(*Prosopis* spp.-dominated). The vegetation description is based on several references, including Brown (1982), Burgess (1995), Dick-Peddie (1993), Muldavin et al. (2000b), Schussman (2006), and NatureServe Explorer (2013).

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-6. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

Table C-6. Apacherian-Chihuahuan Semi-Desert Grassland ecological system crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Loamy Upland	R041XA 001NM
041-Southeastern Arizona Basin and Range	Clay Hills	R041XA 003NM
041-Southeastern Arizona Basin and Range	Gravelly Slopes	R041XA 004NM
041-Southeastern Arizona Basin and Range	Hills	R041XA 005NM
041-Southeastern Arizona Basin and Range	Limy Slopes 16-20" p.z. / *Krameria erecta - Dalea formosa / Bouteloua eriopoda - Hesperostipa neomexicana* (/ littleleaf ratany - featherplume / black grama - New Mexico feathergrass)	R041XA 104AZ
041-Southeastern Arizona Basin and Range	Limy Upland 16-20" p.z. / *Krameria erecta - Nolina microcarpa / Bouteloua eriopoda - Aristida purpurea var. nealleyi* (/ littleleaf ratany - sacahuista / black grama - blue threeawn)	R041XA 105AZ
041-Southeastern Arizona Basin and Range	Loamy Slopes 16-20" p.z. / *Agave palmeri - Nolina microcarpa / Bouteloua curtipendula - Eragrostis intermedia* (/ Palmer's century plant - sacahuista / sideoats grama - plains lovegrass)	R041XA 107AZ
041-Southeastern Arizona Basin and Range	Loamy Upland 16-20" p.z. / *Baccharis pteronioides - Agave palmeri / Bouteloua gracilis - Eragrostis intermedia* (/ yerba de pasmo - Palmer's century plant / blue grama - plains lovegrass)	R041XA 108AZ
041-Southeastern Arizona Basin and Range	Clay Loam Upland 16-20" p.z. / / *Bouteloua gracilis - Hilaria belangeri* (/ / blue grama - curly-mesquite)	R041XA 109AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 16-20" p.z. / *Baccharis pteronioides / Bouteloua curtipendula - Bouteloua gracilis* (/ yerba de pasmo / sideoats grama - blue grama)	R041XA 110AZ
041-Southeastern Arizona Basin and Range	Loamy Swale 16-20" p.z. / / *Bouteloua gracilis - Bouteloua curtipendula* (/ / blue grama - sideoats grama).	R041XA 115AZ
041-Southeastern Arizona Basin and Range	Basalt Hills 12-16" p.z	R041XC 301AZ
041-Southeastern Arizona Basin and Range	Clayey Slopes 12-16" p.z. / / *bouteloua curtipendula - pleuraphis mutica* (/ / sideoats grama - tobosagrass)	R041XC 303AZ
041-Southeastern Arizona Basin and Range	Clay Loam Upland 12-16" p.z. / *Calliandra eriophylla / Pleuraphis mutica - Bouteloua curtipendula* (/ fairyduster / tobosagrass - sideoats grama)	R041XC 305AZ
041-Southeastern Arizona Basin and Range	Granitic Hills 12-16" p.z. / *Eriogonum wrightii - Calliandra eriophylla / Bouteloua curtipendula - Artemisia ludoviciana* (/ bastardsage - fairyduster / sideoats grama - white sagebrush)	R041XC 306AZ
041-Southeastern Arizona Basin and Range	Limestone Hills 12-16" p.z. / *Dalea formosa - fouquieria splendens / Bouteloua curtipendula - Hesperostipa neomexicana* (/ featherplume - ocotillo / sideoats grama - New Mexico feathergrass)	R041XC 307AZ
041-Southeastern Arizona Basin and Range	Limy Slopes 12-16" p.z. / *Calliandra eriophylla - Krameria erecta / Bouteloua eriopoda - Bouteloua curtipendula* (/ fairyduster - littleleaf ratany / black grama - sideoats grama)	R041XC 308AZ

041-Southeastern Arizona Basin and Range	Loamy Swale 12-16" p.z. / / *Bouteloua gracilis - Bouteloua curtipendula* (/ / blue grama - sideoats grama)	R041XC 311AZ
041-Southeastern Arizona Basin and Range	Loamy Upland 12-16" p.z. / *Calliandra eriophylla - Krameria erecta* / *Bouteloua curtipendula - Bouteloua chondrosioides* (/ fairyduster - littleleaf ratany / sideoats grama - sprucetop grama)	R041XC 313AZ
041-Southeastern Arizona Basin and Range	Loamy Slopes 12-16" p.z. / *calliandra eriophylla* / *bouteloua curtipendula* (/ fairyduster / sideoats grama)	R041XC 314AZ
041-Southeastern Arizona Basin and Range	Sandy Loam 12-16" p.z. Deep / *Eriogonum wrightii* / *Bouteloua curtipendula - Digitaria californica* (/ bastardsage / sideoats grama - Arizona cottontop)	R041XC 318AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 12-16" p.z. / *Eriogonum wrightii - Calliandra eriophylla* / *Bouteloua eriopoda - Bouteloua curtipendula* (/ bastardsage - fairyduster / black grama - sideoats grama)	R041XC 319AZ
041-Southeastern Arizona Basin and Range	Granitic Upland 12-16" p.z. / *Calliandra eriophylla - Krameria erecta* / *Bouteloua repens - Bouteloua eriopoda* (/ fairyduster - littleleaf ratany / slender grama - black grama)	R041XC 322AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 12-16" p.z. Loamy / *Eriogonum wrightii* / *Bouteloua curtipendula - Bouteloua hirsuta* (/ bastardsage / sideoats grama - hairy grama)	R041XC 323AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 12-16" p.z. Clayey / *Eriogonum wrightii* / *Bouteloua curtipendula - Pleuraphis mutica* (/ bastardsage / sideoats grama - tobosagrass)	R041XC 330AZ

C-2.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. These are species of conservation or management concern that are associated with healthy grasslands from the BLM Gila District (USDI-BLM 2010). Pronghorn (*Antilocapra Americana),* Black-tailed Prairie Dog (*Cynomys ludovicianus*) and Desert Ornate Box Turtle (*Terrapene ornata*) are included in this list, however they are addressed elsewhere in this assessment as species CEs and have individual conceptual models. Grassland-dependant birds are also treated as an assemblage CE, with a conceptual model.

Amphibians: Great Plains Narrow-mouthed Toad (*Gastrophryne olivacea*), Lowland Burrowing Treefrog (*Smilisca fodiens*), Sonoran Green Toad (*Bufo retiformis*).

Birds: Arizona Grasshopper Sparrow (*Ammodramus savannarum ammolegus*), Baird's sparrow (*Ammodramus bairdii*), Botteri's Sparrow (*Peucaea botterii arizonae*), Ferruginous Hawk (*Buteo regalis*) (breeding population only), Loggerhead Shrike (*Lanius ludovicianus*), Masked Bobwhite (*Colinus virginianus ridgwayi*), Northern Aplomado Falcon (*Falco femoralis septentrionalis*), Northern Harrier (*Circus cyaneus),* Scaled Quail (*Callipepla squamata*), and Western Burrowing Owl (*Athene cunicularia hypogaea*).

Mammals: Banner-tailed Kangaroo Rat (*Dipodomys spectabilis*), Black-tailed Prairie Dog (*Cynomys ludovicianus*), Gunnison's Prairie Dog (*Cynomys gunnisonii*), Pronghorn (*Antilocapra Americana*).

Reptiles: Desert Ornate Box Turtle (*Terrapene ornata*), Slevin's Bunchgrass Lizard (*Sceloporus slevini*).

Additional grassland birds from lists compiled by Gori et al. (2012) include: Brewer's sparrow, Cassin's sparrow, chestnut-collared longspur, clay-colored sparrow, eastern meadowlark, golden eagle, horned lark, lark bunting, lark sparrow, long-billed curlew, McCown's longspur, mountain plover, prairie falcon, sandhill crane, short-eared owl, and vesper sparrow.

C-2.4 Natural Dynamics

The Nature Conservancy did an outstanding review of the Historical Range of Variation for the Semi-Desert Grassland (Schussman 2006) and their work on the mixed native grassland type relates directly to the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE and is the primary source for this section. However, this CE does not include other grasslands addressed in Schussman (2006) such as the valley bottom or black grama grasslands.

These semi-desert grasslands are complex with many stands having a shrub or stem succulent component (*Agave* and *Yucca* spp.) under natural conditions (Burgess 1995). This woody component increases in density over time in the absence of disturbance such as fire (Burgess 1995, Gori and Enquist 2003, Schussman 2006). Under historic natural conditions (also called natural range of variability, NRV), this ecosystem ranges from open perennial grasslands with low cover of shrubs to grasslands with a moderately dense shrub layer and succulent layer (Burgess 1995, Gori and Enquist 2003). An exception is that some stands with deep argillic horizons appear resistant to shrub and tree invasion without disturbance (McAuliffe 1995).

It is well documented that frequent stand replacing fire (fire return interval (FRI) of 2.5 to 10 years) was a key ecological attribute of this semi-desert grassland ecosystem historically before 1890 (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980). Other evidence of the importance of fire in maintaining desert grasslands includes the widespread conversion of grasslands to shrublands during the century of fire suppression (McPherson 1995) and the results of prescribed burning on decreasing shrub cover and increasing grass cover (Bock and Bock 1992, Robinett 1994). Additional evidence that frequent fire is a key ecological attribute of this ecosystem is that many common shrubs, subshrubs and cacti are fire-sensitive and individuals are killed when top burned, at least when they are young (< 10 years old) (McPherson 1995), while native perennial grasses quickly recover from burning (Bock and Bock 1992; Martin 1983; Wright 1980). Below (Figure C-5) is a conceptual state-and-transition model of this ecosystem under historic natural range of variation (NRV) conditions.

Herbivory by native herbivores in the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe is varied and ranges from invertebrates and rodents to pronghorn (Finch 2004, Parmenter and Van Devender 1995, Whitford et al. 1995). Soil dwelling invertebrates include tiny nematodes and larger termites and ants and are important in nutrient cycling and effect soil properties, such as bulk density (Whitford et al. 1995). Above ground invertebrates such as grasshoppers can significantly impact herbaceous cover when populations are high.

Herbivory by native mammals also impacts these grasslands. Historically populations of large mammals such as pronghorn (*Antilocarpa Americana*), mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) were once abundant in this ecosystem (Parmenter and Van Devender 1995). Populations were greatly reduced and in the case of pronghorn, extirpated, during the 1800s and early 1900s, but effective game management has restored many populations, although habitat changes will limit restoration in other areas (Parmenter and Van Devender 1995). The historic impact of large native ungulates on this ecosystem is not known, however in the case of wintering elk it may have been significant locally. The current impact is assumed to be relatively small in this ecosystem.

Herbivory from native small mammals such as rodents, is significant as they are the dominant mammals in the semi-desert grassland ecosystem. There is also high diversity of these rodents, especially ground-dwelling ones such as spotted ground squirrels (*Spermophilus spilosoma*), and bannertail and Ord kangaroo rats (*Dipodomys spectablilis* and *D. ordii*). These burrowing rodents have a substantial effect on vegetation composition, soil structure and nutrient cycling (Finch 2004, Parmenter and Van Devender 1995). Historically, black-tail prairie dogs (*Cynomys ludovicianus*) had extensive colonies but were greatly reduced or extirpated from semi-desert grasslands in Arizona by 1960s and their numbers and impacts are still small (Parmenter and Van Devender 1995). Other rodents such as kangaroo rats are still abundant in semi-desert grasslands.

Invertebrate animals are also significant in semi-desert grassland. They are both abundant and extremely diverse ranging from single celled protozoans, bacterial and soil nematodes and mites to larger arachnids, millipedes, cockroaches, crickets, grasshoppers, ants, beetles, butterflies, moths, flies, bees, wasps, and true bugs (Whitford et al. 1995). Invertebrates are important for nutrient cycling, pollination, and subterranean species of ants and termites can impact soil properties such as bulk density, infiltration permeability and storage (Whitford et al. 1995). Grasshoppers feed on grasses and forbs and can consume significant amounts of forage when their populations are high. Many species of butterflies, flies, bees, and moths are important for pollination. Some species such as Yucca moths (*Tegeticula yuccasella*) and *Yucca* species have obligate mutualistic relationships (Whitford et al. 1995). More study and review is needed to fully understand the many functional roles animals have within the semi-desert grassland ecosystem.

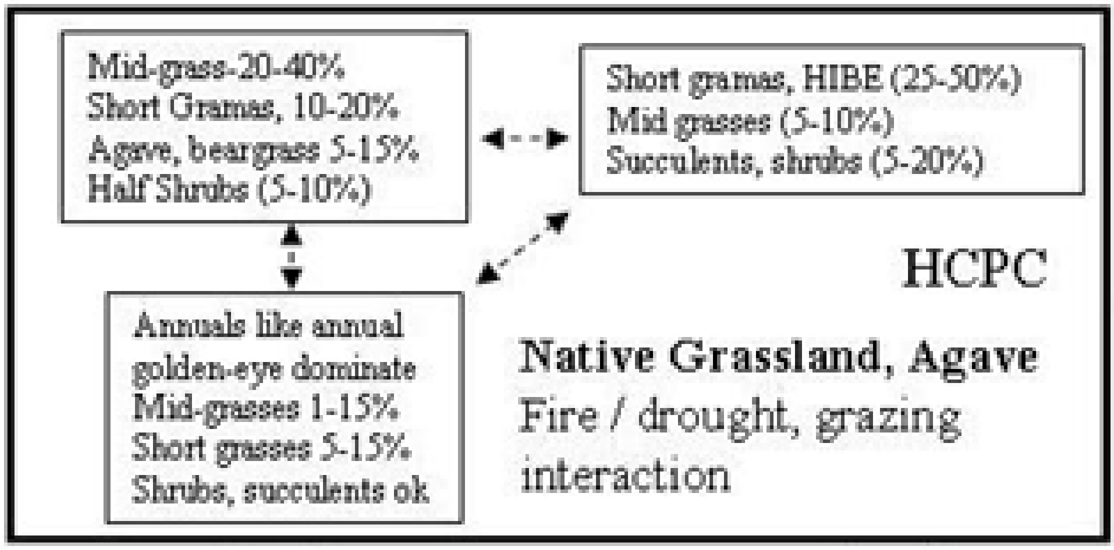
A good condition/proper functioning mixed semi-desert grassland ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; shrub cover is generally low; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 2.5 to 10 years; soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. vegetation structure is converted from perennial grass dominated to shrub dominated vegetation, or vegetation is dominated by non-native species such as Lehmann lovegrass (*Eragrostis lehmanniana*). Impacts from herbivory have significantly altered the vegetation structure of plant species composition, i.e. low cover of native grasses, high cover of seral species (such as *Arisida* spp. or annuals. Characteristic birds, mammals, reptiles, and insects species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub-horizons. The fire regime is no longer a high-frequency one, rather fires are occurring at longer intervals, allowing shrubs or trees to become established.

C-2.4.1 Natural Dynamics Model

Conceptual historic state-and-transition models were developed by several ecology teams (Schussman 2006, Muldavin et al. 2012), and NRCS for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe. Below is a conceptual historic state and transition model of the Historic Climax Plant Community (HCPC) for NRCS ESD R041XA107AZ from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE (Figure C-5).

Figure C-5. Conceptual state and transition model of historic conditions for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE.. This model is the Historic Climax Plant Community (HCPC) portion of a larger model from NRCS ESD R041XA107AZ Loamy Slopes 16-20" p.z., *Agave palmeri - Nolina microcarpa / Bouteloua curtipendula - Eragrostis intermedia*.



From ESD R041XA107AZ:

Description of State and Transition Model

"The historic native state includes the plant communities that occur on the site, including the historic climax plant community. This state includes other plant communities that naturally occupy the site following fire, drought, flooding, herbivores, and other natural disturbances. The historic climax plant community represents the natural climax community that eventually re-occupies the site with proper management.

The potential plant community on this site is dominated by warm season perennial mid-grasses. The major grass species are well dispersed throughout the plant community. Stands of Palmer agave occur in dense patches and are not well dispersed through areas of the site. Several species of low shrubs, cacti and other succulents, and forbs are well represented in this plant community. The aspect is open grassland to savannah. North slopes will often have an open canopy of oaks and / or juniper. South slopes will be agave dotted grassland.

Naturally occurring fires in June-August were an important factor in shaping this plant community. Fire-free intervals range from 10-20 years. Without disturbance like grazing or fire, perennial mid-grasses can become decadent and forbs like annual goldeneye, cudweed and camphorweed can increase to dominate the plant community. This site is the principal habitat for the Agave Palmeri in southeastern Arizona, an important food source for the endangered lesser long-nosed bat in June, July, and August. Dense stands of this species occur scattered throughout areas of this site. Nectar production in these stands ranges from 6-10 gallons per acre.

Periodic drought can occur in this LRA and cause significant grass mortality. Droughts in the early 30s, mid 50s, 1975-1976, 88-89, 95-96 and 2002 resulted in the loss of much of the grass cover on this site.

The site recovers rapidly, however, due to excellent covers of stone, cobbles and gravel and the favorable climate that prevails in this common resource area. "

C-2.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-2.5.1 List of Primary Change Agents

Occurrences of this grassland ecological system can be directly affected by livestock grazing, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table C-7 identifies the most likely impacts associated with each of these stressors.

Table C-7. Stressors and their likely impacts on the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at inappropriate stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts in species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Swetnam and Baisan 1996).
Recreation	This mostly relates to off road vehicle use, which creates addition roads and trails that fragment grassland and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes by changing surface flows such as when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).

Stressor	Impacts
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes (e.g. fire suppression to protect infrastructure), increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Agriculture	This stress contributes to increased erosion, direct habitat loss/conversion, fragmentation, increased groundwater pumping, and invasive non-native species dispersal.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, changes in woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003).
Invasive Non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*. These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Enquist 2003, Schussman 2006a).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.

C-2.5.2 Altered Dynamics

These native mixed semi-desert grasslands are the dominant grassland type within this ecoregion and range from open grasslands with low shrub canopy cover (less than 10% cover) to denser grassland with higher shrub and succulent cover. Over time without fire or other disturbance, stands become dominated by woody vegetation and convert to shrublands or woodlands (Gori and Enquist 2003). Conversion to juniper woodlands or mesquite or creosotebush shrublands is common when trees or mesquite exceed 15% cover (Gori and Enquist 2003). There are many interacting factors that have contributed to the expansion of shrubs into grassland, including climate, soils, fire, herbivory, grazing history, and existing vegetation. These grasslands were historically maintained as open grasslands with low shrub cover by fire return intervals of 2.5 to 10 years (Brown and Archer 1999, McPherson 1995, Robinett 1994, Wright 1980). The interaction of drought and livestock grazing tends to diminish perennial grass cover and abundance, to the extent that herbaceous fuels are lowered so that fire frequency declines, and the lowered fire frequency permits a more rapid rate of shrub increase (Brown and Archer 1999, McPherson 1995, Robinett 1994, Wright 1980). Gori and Enquist (2003) found there is a loss of perennial grasses and increases of bareground over time as grasslands are converted to shrublands. If not protected by surface rock, top soil erosion can occur, changing the site to be less suitable for grass recolonization (McAuliffe 1995).

Although fire may play a more important role in controlling shrub encroachment and maintaining perennial grass cover in the mixed native grassland types in AZ, other disturbances may be the cause of shrub encroachment in the black gramma and valley bottom types (which are not part of this CE concept).

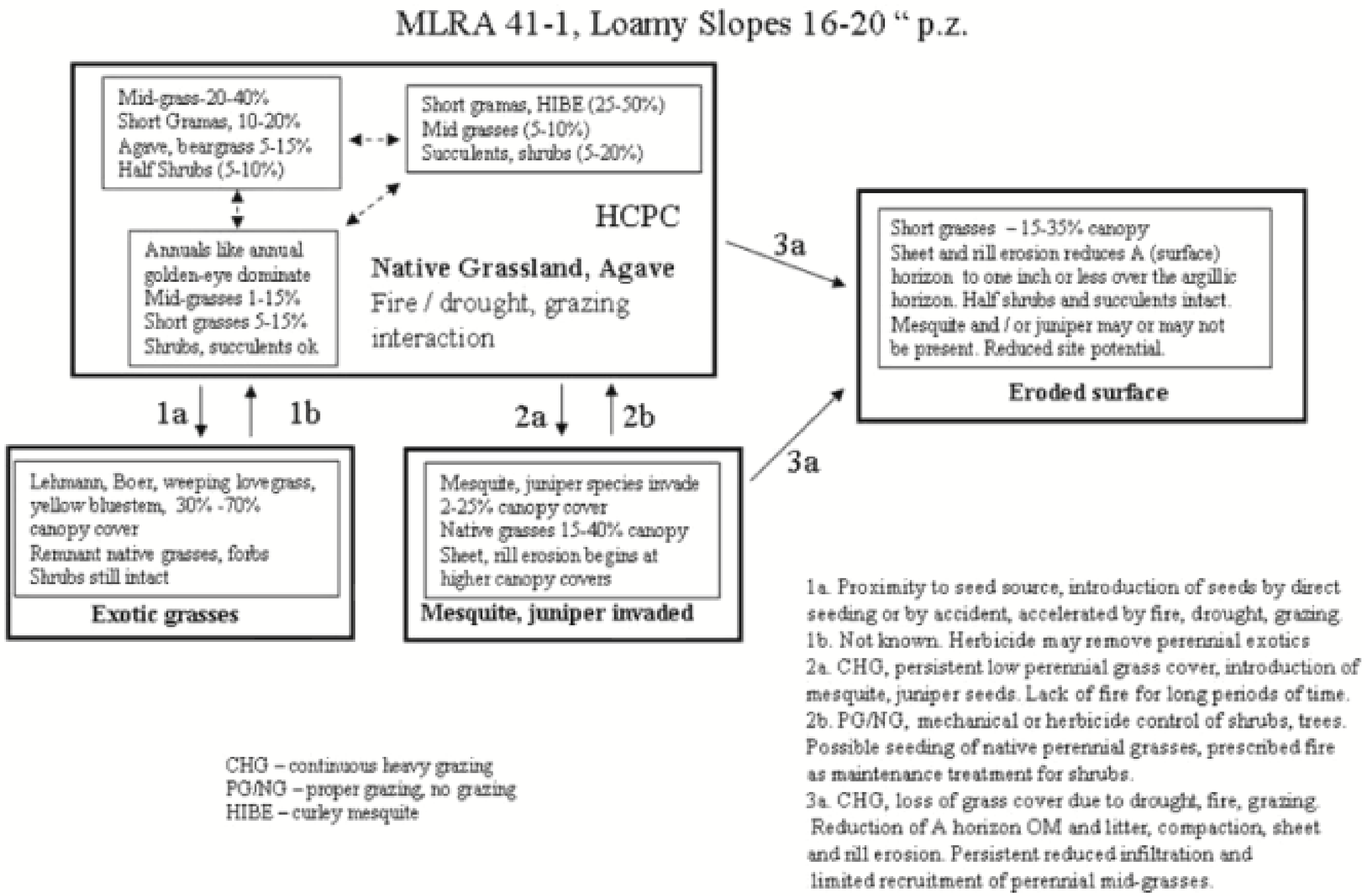
Hydrological alterations also occurred in many semi-desert grasslands during early anglo-American settlement time with a period of arroyo formation from 1865 to 1915 (Cooke and Reeves 1976). During this time many broad valley bottom drainages were incised, lowering water tables. This resulted in changes to more xeric vegetation because of decreased water availability, as well as increased sediment movement, altered hydrologic relationships, and loss of productive land (Cooke and Reeves 1976). There is debate about the causes of these hydrologic changes. Cooke and Reeves (1976) found strong evidence that arroyo formation in this ecoregion was initiated by building ditches, canals, roads and embankments along channels that altered valley floor hydrology.

The introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has greatly impacted many semi-desert grasslands in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003). Anable et al. (1992) and Cable (1971), found Lehmann lovegrass is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.

C-2.5.3 Altered Dynamics Model

Conceptual state-and-transition models were developed by several ecology teams (Schussman 2006, Muldavin et al. 2012), and NRCS for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem. Below is a conceptual state and transition model of the current conditions for the for NRCS ESD R041XA107AZ from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE (Figure C-6). It includes the Historic Climax Plant Community (HCPC) as part of the full model.

Figure C-6. Conceptual state and transition model of current conditions for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE. This model is from NRCS ESD R041XA107AZ Loamy Slopes 16-20" p.z. / *Agave palmeri - Nolina microcarpa / Bouteloua curtipendula - Eragrostis intermedia* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



From ESD R041XA107AZ:

Description of State and Transition Model

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrow indicating introduction of non-native forage grasses such as *Eragrostis Lehmanniana* or *E. curvula*; invasion by shrubs and small trees (primarily species of *Prosopis* and *Juniperus*) resulting from extended periods of lack of fire; and an eroded surface with low grass cover (including reduction or loss of A soil horizon, reduced soil infiltration, soil organic material, ground cover, litter, and increased soil compaction, sheet and rill erosion).

The model also indicates the possibility of restoration of the HCPC with the application of both mechanical and herbicide treatments. Many acres of degraded grasslands within the MAR, particularly in New Mexico (both mesquite and creosote invaded sites) have been the target of restoration efforts with both mechanical removal of shrubs and herbicide treatments (Lister, pers comm.), combined with reintroduction of the native perennial grasses and prescribed fire.

Descriptions of altered states are excerpted from Ecological Site Description (ESD) for R041XA107AZ below:

"Exotic grasses

This state occurs where non-native lovegrass species or yellow bluestem, have invaded from adjacent areas or roads and ROWs with a seed source. As these species increase to dominate the plant community, native perennial grasses and forbs decrease to remnant amounts. Fire will usually act to increase species like Lehmann lovegrass. The native half shrubs seem to be able to stay in the plant community. It is not know how Agave Palmeri fares under this condition.

Shrub invaded

This state occurs where mesquite, wait a bit mimosa, one-seed juniper and / or alligator juniper have invaded or increased to dominate the plant community. This occurs in the absence of fire for long periods of time, with continuous grazing and in the presence of a seed source of these species. As canopy levels of trees and shrubs approach 30%, sheet and rill erosion can begin to accelerate.

Eroded surface

This state occurs where severe soil compaction and trailing has resulted in loss of plant cover and an increase in runoff. Sheet and rill erosion accelerates and the surface (A) horizon is removed faster than it can be replaced by down-slope soil movement and weathering of the ridgetops. When the subsurface argillic (clayey) horizons are exposed, the site has lost its potential productivity. The plant community will shift from warm season plants to cool season plants and the ratio of runoff to infiltration will increase.

With continuous, heavy grazing, mid-grasses are removed from the plant community and replaced by short grasses such as curly mesquite, slender grama and sprucetop grama. With severe deterioration, shrubby species such as wait-a-bit mimosa, one-seed and alligator juniper, and mesquite can increase to dominate the site. With good management, native mid-grasses will be able to regain their dominance in the plant community, unless soil erosion is severe enough to strip away the surface horizon. Mesquite and Lehmann lovegrass are at the upper limits of their elevation range, but can increase on the site, especially below 5000 feet elevation and on southern exposures. Climatic warming may allow these two species to push higher in elevation as time goes by. Naturally occurring fires in June-August were an important factor in shaping this plant community. Fire-free intervals range from 10-20 years. Without disturbance like grazing or fire, perennial mid-grasses can become decadent and forbs like annual goldeneye, cudweed and camphorweed can increase to dominate the plant community. This site is the principal habitat for the Agave Palmeri in southeastern Arizona, an important food source for the endangered lesser long-nosed bat in June, July, and August. Dense stands of this species occur scattered throughout areas of this site. Nectar production in these stands ranges from 6-10 gallons per acre.

Periodic drought can occur in this LRA and cause significant grass mortality. Droughts in the early 30s, mid 50s, 1975-1976, 88-89, 95-96 and 2002 resulted in the loss of much of the grass cover on this site. The site recovers rapidly, however, due to excellent covers of stone, cobbles and gravel and the favorable climate that prevails in this common resource area."

C-2.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-2.6.1 Key Ecological Attributes

Table C-8 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-8. Key Ecological Attributes (KEA) used to determine the ecological status of Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Matrix/Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres) for large patch to 2000 to 405,000 hectares (approximately 5000 to 1,000,000 acres) for matrix.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native grassland fauna will provide information on the condition of these important components of semi-desert grasslands (Finch 2004).	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, Parmenter and Van Devender 1995, Whitford et al. 1995). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Biotic Condition:* Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of semi-desert grasslands, as well as soil structure and water infiltration, and species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Gori and Enquist 2003). High cover of native perennial grass and low cover of woody vegetation define this grassland CE.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. For example, Gori and Enquist (2003) found grass cover declined with increased shrub cover in these mixed grasslands, which ranged from open grasslands with low shrub canopy cover (less than 10%) towards higher shrub cover and ultimately to convert (> 35% total shrub canopy cover or > 15% mesquite or juniper cover) to shrublands without frequent fire. High cover of native perennial grass and low cover of woody vegetation define this grassland CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing sother structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.

KEA Class: Name	Definition general	Rationale general	Stressors general
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. For semi-desert grassland frequent fire (FRI of 2.5-10 years) is key to reducing shrub cover and preventing conversion from perennial grassland to shrubland or juniper woodland (Gori and Enquist 2003).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

C-2.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table C-8 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-9. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-9. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table C-9. Key Ecological Attributes (KEA) for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-2.8 Conceptual Model Diagrams

See Figure C-5 and Figure C-6 above.

C-2.9 References for the CE

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Foothill Woodlands

C-3 Madrean Encinal

C-3.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Madrean Encinal (CES305.795)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Madrean Juniper Savanna (CES305.730) - codominated by oak
- Madrean Pinyon-Juniper Woodland (CES305.797) - codominated by oak
- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735) – with scattered oaks

C-3.2 Summary

Madrean Encinal occurs in foothills, canyons, alluvial fan piedmonts (bajadas) and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north into Trans-Pecos Texas, southern New Mexico and sub-Mogollon Arizona. Stands occur down to 900 m elevation in southern Sonora, but generally range from around 1200-1350 m intermixed with semi-desert grasslands, and extend up to 1650-2200 m as pure oak patches within Madrean montane forests and woodlands (Brown 1982; Figure C-7). Soils are variable but generally thin and rocky. Soils are variable but generally thin and rocky. Where encinal occurs within grasslands, it generally occupies the rockier substrates or is restricted to drainages (Brown 1982).

Figure C-7. Madrean Encinal steep west-facing slope above the pine-oak corridor of Rattlesnake Canyon (http://azfirescape.org).

Adjacent ecosystems may include Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Lower Montane Pine-Oak Forest and Woodland [CES305.796] at higher elevations and Mogollon Chaparral (CES302.741), Madrean Juniper Savanna (CES305.730) and Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CES302.735 at lower elevations. The environmental description is based on several references, including Brown (1982), Dick-Peddie (1993), Ffolliott (1999a), McAuliffe (1995), Muldavin et al. (1998), Muldavin et al. (2000b), NatureServe Explorer (2013), Schussman (2006b), and Stuever and Hayden (1997a).

Stands of this ecosystem are dominated by diagnostic Madrean evergreen oak tree species, including *Quercus arizonica, Quercus emoryi, Quercus grisea, Quercus oblongifolia* in the U.S. and northern Mexico, and *Quercus albocincta, Quercus chihuahuensis, Quercus chuchuichupensis*, and *Quercus santa-clarensis* further south in southern Chihuahua and Durango, Mexico. *Arbutus arizonica* or *Arbutus xalapensis* may be present with the evergreen oaks in some stands. Other evergreen tree species may be present with lower cover (not codominant), including *Pinus cembroides, Pinus discolor, Juniperus coahuilensis*, and *Juniperus deppeana* at lower elevations and *Pinus arizonica, Pinus engelmannii, Pinus leiophylla*, or *Pinus strobiformis* at montane elevations. Chaparral species such as *Arctostaphylos pungens, Cercocarpus montanus, Frangula betulifolia (= Rhamnus betulifolia)*, *Purshia* spp., *Garrya wrightii, Quercus intricata, Quercus toumeyi*, *Quercus turbinella,* or *Rhus* spp. are common in shrub layers, but do not dominate the vegetation. Other shrubs present may include rosette shrubs such as *Dasylirion wheeleri* or *Yucca bacata;* and cacti*, Opuntia engelmannii, Opuntia imbricata,* or *Opuntia phaeacantha.* The herbaceous layer is usually prominent, especially in inter-spaces between trees in open woodlands. Dominant species are typically warm-season perennial grasses such as *Aristida* spp., *Bouteloua gracilis, Bouteloua curtipendula, Bouteloua radicosa, Bouteloua rothrockii, Digitaria californica, Eragrostis intermedia, Eragrostis mexicana, Hilaria belangeri, Leptochloa dubia, Muhlenbergia emersleyi, Muhlenbergia longiligula, Muhlenbergia pauciloba*, *Piptochaetium fimbriatum* or *Schizachyrium cirratum*, species typical of desert grasslands and steppe. This woodland group includes seral stands dominated by short (2-5 m tall) Madrean tree oaks, typically with a strong graminoid layer. In transition areas with drier chaparral, the stands of chaparral may have scattered Madrean tree oak species, but these oaks have sparse cover and do not form a layer. The vegetation description is based on several references, including Brown (1982), Dick-Peddie (1993), Ffolliott (1999), Muldavin et al. (2000b), NatureServe Explorer (2013), Schussman (2006b), and Stuever and Hayden (1997a).

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-10. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

Table C-10. Madrean Encinal ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Granitic Hills 16-20" p.z. - *Quercus emoryi* - Quercus *arizonica* / *Nolina microcarpa* - *Erythrina flabelliformis* / *Bouteloua curtipendula* - *Schizachyrium cirratum* (Emory oak - Arizona white oak / sacahuista - coralbean / sideoats grama - Texas bluestem)	R041XA102AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 16-20" p.z. - *Quercus emoryi* - *Juniperus deppeana* / *Eriogonum wrightii* - *Nolina microcarpa* / *Bouteloua curtipendula* - *Eragrostis intermedia* (Emory oak - alligator juniper / bastardsage - sacahuista / sideoats grama - plains lovegrass)	R041XA111AZ
041-Southeastern Arizona Basin and Range	Sandy Wash 16-20" p.z. (QUEM, QUAR) - *Quercus arizonica* / / *Bouteloua curtipendula* - *Leptochloa dubia* (Emory oak - Arizona white oak / / sideoats grama - green sprangletop)	R041XA112AZ
041-Southeastern Arizona Basin and Range	Granitic Upland 16-20" p.z. - *Quercus emoryi* / *Calliandra eriophylla* - *Fouquieria splendens* / *Bouteloua chondrosioides* - *Bouteloua hirsuta* (Emory oak / fairyduster - ocotillo / sprucetop grama - hairy grama)	R041XA117AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 16-20" p.z. Deep - *Quercus arizonica* / *Eriogonum wrightii* / *Bouteloua curtipendula* - *Bothriochloa barbinodis* (Arizona white oak / bastardsage / sideoats grama - cane bluestem)	R041XA127AZ

C-3.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE from the BLM Gila District (USDI BLM 2010); TE/SOC/SOI Species Associations: Madrean Encinal Woodland from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009); from the Arziona State Wildlife Action Plan (AZGFD 2012); and from the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006).

Amphibians: Tarahumara Frog (*Lithobates tarahumarae*); barking frog ( )

Birds: Elegant Trogon (*Trogon elegans*); whiskered screech owl (*Otus trichopsis*); Gould’s turkey, Montezuma quail, Mexican jay, bridled titmouse,

Mammals: Jaguar (*Panthera onca*); Black Bear (*Ursus americanus*); Arizona Gray Squirrel (*Sciurus arizonensis***);** Mexican long-nosed bat (*Leptonycteris nivalis*); lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*); southern pocket gopher ( )

Reptiles: New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*); Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*); brown vinesnake (*Oxybelis aeneus*)

Invertebrates: Huachuca Giant Skipper (*Agathymus evansi*), Pygmy Sonorella (*Sonorella micra*); Huachuca talussnail, Rosemont talussnail, (and many other talus snails)

Vascular Plants: Spreading Marina (*Marina diffusa*), Chiricahua Mock Pennyroyal (*Hedeoma costatum*), Rothrock's Grama (*Bouteloua rothrockii*)

C-3.4 Natural Dynamics

Under historic natural conditions (also called natural range of variability, NRV), the Madrean Encinal ecosystem varies considerably in tree density ranging from very open woodlands and treed savannas (5-15% cover) with a perennial grass-dominated understory in uplands, to moderately dense oak woodlands (20-40% tree cover) in drainages and on north-facing slopes. The understory of good condition stands generally has high cover of perennial grasses and low cover of shrubs such as *Mimosa* and this good condition of the stand is maintained with frequent fires. Turner et al. (2003) documented a trend from more open woodlands and savannas to denser woodlands with higher cover of species of *Juniperus* and *Prosopis* over the last 150 years. Regeneration of oaks following disturbance is from re-sprouting rather than acorns because of the dry conditions (Germaine and McPherson 1999).

Although there is not much encinal-specific information on fire return intervals (FRI) available, it is thought to be similar to adjacent ecosystems primarily the semi-desert grassland (FRI of 2.5 to 10 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980) and the pine-oak woodlands (FRI of 3- 7 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980). Fire season in encinal was probably similar to that of other Madrean woodlands and grasslands, occurring predominantly before the summer monsoon between April and June when vegetation is dry and ignition sources from dry lightning strikes are common (Swetnam and Betancourt 1990). Post disturbance regeneration (such as after stand-replacing fire) mostly occurs from re-sprouting from trees roots. Successful regeneration from acorns is related to annual precipitation (Germaine and McPherson 1999).

The understory of poor condition stands with less frequent fires or experiencing extended drought may have significant shrub invasion by species of *Arctostaphylos, Fouquieria, Mimosa, Prosopis,* and *Juniperus* and reduction of perennial grass cover (Schussman 2006a).

Over the last century, the woody component has increased in density over time in the absence of disturbance such as fire (Turner et al. 2003, Burgess 1995, Gori and Enquist 2003, Schussman 2006a). This is correlated to a decrease in fire frequency that is related to a reduction of fine fuels that carry fire because of extensive livestock grazing. Frequent, stand replacing fire was likely a key ecological attribute prior to 1890 (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980).

Herbivory by native herbivores in the Madrean Encinal is likely very similar to semi-desert grasslands, at least for the more open stands, which range from invertebrates and rodents to pronghorn (Finch 2004, Paramenter and Vandevender 1995, Whitford et al. 1995). Encinal soils are also likely similar to grasslands with soil dwelling invertebrates, including tiny nematodes and larger termites and ants, which are important in nutrient cycling and effect soil properties, such as bulk density (Whitford et al. 1995). Above-ground invertebrates such as grasshoppers can significantly impact herbaceous cover when populations are high. Oak acorn and other fruit consumption and seed caching by birds such as jays and native mammals such as deer and bears also impacts encinal.

Herbivory from native small mammals such as burrowing rodents (e.g. ground squirrels) is significant in the semi-desert grassland ecosystem and likely also in encinal. These burrowing rodents have a substantial effect on vegetation composition, soil structure and nutrient cycling (Finch 2004, Parmenter and Van Devender 1995).

Invertebrate animals are also significant in encinal as they are in grasslands. They are both abundant and extremely diverse ranging from single celled protozoans, bacterial and soil nematodes and mites to larger arachnids, millipedes, cockroaches, crickets, grasshoppers, ants, beetles, butterflies, moths, flies, bees, wasps, and true bugs (Whitford et al. 1995). Invertebrates are important for nutrient cycling, pollination, and subterranean species of ants and termites can impact soil properties such as bulk density, infiltration permeability and storage (Whitford et al. 1995). Grasshoppers feed on grasses and forbs and can consume significant amounts of forage when their populations are high. Many species of butterflies, flies, bees, and moths are important for pollination. Some species such as Yucca moths (*Tegeticula yuccasella*) and *Yucca* species have obligate mutualistic relationships (Whitford et al. 1995). More study and review is needed to fully understand the many functional roles animals have within the Madrean Encinal ecosystem.

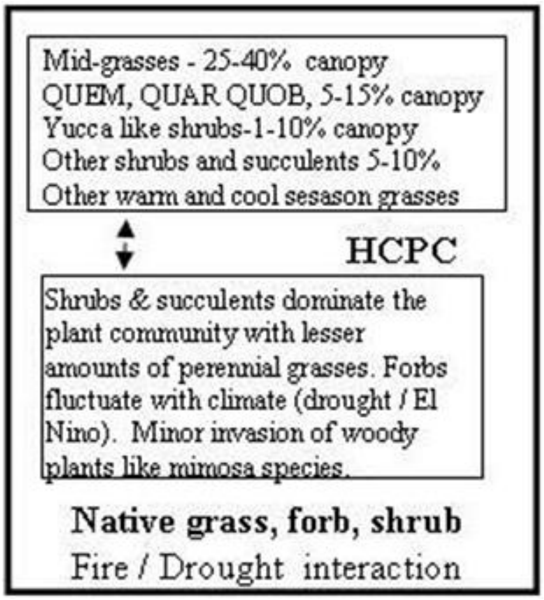
A good condition/proper functioning Madrean Encinal ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of surface fires every 2.5 to 10 years; soils have not been excessively eroded. The structure is that of open woodlands or savannas with an understory of native perennial grasses.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. vegetation structure is converted from open woodlands or savannas with a native perennial grass undersotry to more dense woodlands with significant cover of non-native grasses such as Lehmann lovegrass (*Eragrostis lehmanniana*). Impacts from herbivory have significantly altered the vegetation structure of plant species composition, i.e. low cover of native grasses, high cover of seral species (such as *Aristida* spp.) or annuals. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub-horizons. The fire regime is no longer a short-return interval, but has been altered by suppression, which in turn has lead to increasingly dense cover of the oaks.

C-3.4.1 Natural Dynamics Model

A conceptual state-and-transition model for the Historic Climax Plant Community (HCPC) was extracted from an Ecological Site Description (ESD) developed by staff from USDA Natural Resource Conservation Service (Figure C-8). The full conceptual state-and-transition model for the Granite Hills ESD was representative of the Madrean Encinal and is referred Granitic Hills 16-20" p.z, Q*uercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium* *cirratum* from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. Note fire and drought are the key ecological variables.

Figure C-8. Conceptual state and transition model of historic conditions for the Madrean Encinal CE. This model is the Historic Climax Plant Community (HCPC) portion of a larger model from NRCS ESD R041XA102A2Z Granitic Hills 16-20" p.z, *Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum.*



C-3.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Encinal ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-3.5.1 List of Primary Change Agents

Occurrences of this grassland ecological system are directly affected by inappropriate grazing by livestock, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table C-11identifies the most likely impacts associated with each of these stressors.

Table C-11. Stressors and their likely impacts on the Madrean Encinal ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at inappropriate stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Kaib et al. 1996, Swetnam and Baisan 1996).
Over- harvesting of fuelwood	Fuel wood cutting has impacted stands in southeastern Arizona historically and is still common for domestic use (Bahre 1991, Bennet 1992). Change stands structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment encinal and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, changed woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003).

Stressor	Impacts
Invasive non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*. These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Enquist 2003, Schussman 2006b).
Climate change	Alteration of precipitation and evapotranspiration rates and timing may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.

C-3.5.2 Altered Dynamics

These oak woodlands and savannas are characterized by a strong perennial grass layer and are driven by many of the same ecological processes as semi-desert mixed grassland, primarily frequent fire and drought (USDA-USFS 2009.)

It is generally agreed that fire regime has been altered for encinal by passive fire suppression via removal of fine fuels through livestock grazing, as well as active suppression over the last 100 years. This has reduced the number of surface fires, permitting a buildup in woody fuels resulting in increased fire severity when fires occurs in encinal and adjacent vegetation types like semi-desert grasslands and pine-oak woodlands across much or the southwestern US and adjacent Mexico (Kaib et al. 1996, Swetnam and Baisan 1996). Reduced fire frequency is a disturbance of the natural fire regime and results in increased cover of woody plants (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003). The increase in woody species in the Madrean Encinal has changed species composition, in some areas, from oak dominated woodlands or savanna to mesquite and/or juniper dominated woodlands (Turner et al. 2003).

Livestock grazing in Madrean Encinal is currently a common practice in both the United States and Mexico with grazing occurring in virtually all of Mexico's and in roughly 75 % of the United States' oak woodlands (McPherson 1997). Livestock grazing can affect the structure and composition of Madrean oak woodlands, as well as soil structure and water infiltration (USDA-USFS 2009).

Other management practices that cause disturbance in Madrean Encinal woodland are road building, recreation management, fire management, and ecosystem restoration activities. As with livestock grazing, the direct, indirect and cumulative effects of these activities are analyzed and mitigated through site specific NEPA processes (USDA-USFS 2009).

The introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has greatly impacted many semi-desert grasslands and encinal in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003). Anable et al. (1992) and Cable (1971), found Lehmann lovegrass is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.

Historic fuel wood cutting for mining and domestic use in was common in Madrean Encinal in southeastern Arizona until the late 1800's, and is still common in Arizona and northern Mexico today (Bahre 1991, Bennet 1992). Although fuel wood harvesting had dramatic effects historically its consequence were generally local and short-lived (Turner et al. 2003).

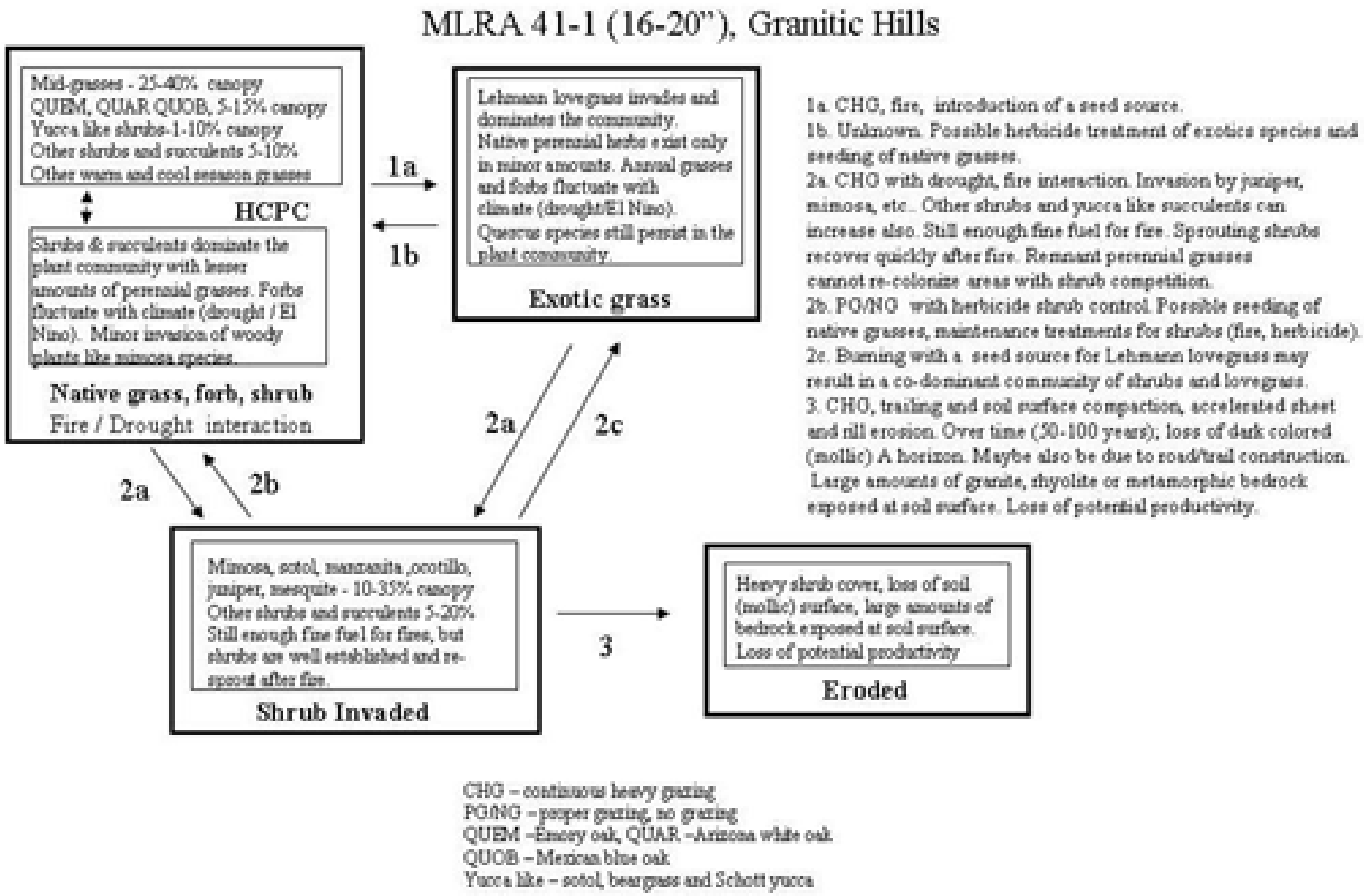
Fragmentation of Madrean Encinal and closely associated semi-desert grasslands has a large impact especially around urban areas and has increased greatly in the last 70 years (Bahre 1991).

Fragmentation has been well documented as an ecological stressor and threat in many assessments and reports (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b). Urban development has lead to the loss and fragmentation of grassland and encinal vegetation and the alteration of ecological processes, such as frequent low intensity surface fire, that used to maintain the vegetation with home, road and fence building (Bahre 1991, Finch 2004, McPherson 1997).

C-3.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed for the Granite Hills ESD Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum (R041XA102A2Z) from the 041-Southeastern Arizona Basin and Range MLRA by the staff from USDA Natural Resource Conservation Service at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD (Figure C-9). This model generally represents the Madrean Encinal ecosystem. It includes the Historic Climax Plant Communitiy (HCPC) as well as altered states (dominance of Lehman's lovegrass, increased cover of shrubs beyond acceptable ranges, a degraded eroded state after loss of ground cover) and changes in the transitions from the above NRV.

Figure C-9. Conceptual state and transition model of current conditions for the Madrean Encinal CE. This model is from NRCS ESD R041XA102A2Z Granitic Hills 16-20" p.z, *Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



From ESD R041XA102AZ:

Description of State and Transition Model

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrow indicating introduction of non-native forage grasses such as *Eragrostis Lehmanniana* or *E. curvula*; increases in desert shrubs (*Prosopis* spp., *Fouquieria* sp. , *Mimosa* spp.) and small trees cover (primarily species of *Juniperus* not characteristic of this community) resulting from extended periods of lack of fire; and an eroded surface with low grass cover (including reduction or loss of A soil horizon, reduced soil infiltration, soil organic material, ground cover, litter, and increased soil compaction, sheet and rill erosion).

Excerpted from NRCS ESD R041XA102AZ:

"The potential plant community is a diverse mixture of warm and cool season perennial grasses, ferns, forbs, succulents and shrubs. A tree canopy of 5-15% Mexican live-oak species occurs on the site, giving it a savannah appearance. Most perennial herbaceous species are well dispersed throughout the plant community. A few species, however, occur only under the canopies of trees.

With continuous heavy grazing, mid-grasses like sideoats grama, plains lovegrass, crinkleawn and green sprangletop are removed and replaced by annual grasses and forbs. Naturally occurring wildfires in June-August are an important factor to shaping this plant community. Fire-free intervals range from 10-20 years. In the absence of fire, this site gets shrubby with increases in species like terpentine bush, mimosas, bricklebush, goldeneye, sotol and amole. Oak species on the site are very tolerant of fire. Well-developed covers of stones, cobbles, and gravel protect the soil from erosion after fire or heavy grazing. Trees per acre run from 5-30. Agave Palmeri plants average 5-60 per acre. Without periodic disturbance like fire or grazing, grass species can become decadent and annuals like goldeneye can become dominant, especially in the years with wet winter-spring seasons.

Periodic drought can occur in this land resource area and cause significant grass mortality. Droughts in the early 30s and mid 50s, 1975-76 and 1988-89, 1995-96 and 2002 resulted in the loss of much of the grass cover on this site. The site recovers rapidly, due to good covers of gravels and cobbles and the favorable climate prevailing in this common resource area."

C-3.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-3.6.1 Key Ecological Attributes

Table C-12 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-12. Key Ecological Attributes (KEA) used to determine the ecological status of Madrean Encinal ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: Name	Definition general	Rationale general	Stressors general
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Size/Extent:* Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of encinal, as well as soil structure and water infiltration, and species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Kaib et al. 1996; Swetnam and Baisan 1996).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open to closed oak tree canopy with moderate to high cover of native perennial grass defines the Madrean Encinal CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing sother structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. For Madrean Encinal frequent fire (FRI of 2.5-10 years) is key to maintaining an open oak canopy, maintaining a perennial grass understory (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980) and the pine-oak woodlands (FRI of 3-7 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

C-3.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in Table C-12 also encompass the four fundamentals of rangeland health (43CFR4180, 2010), as shown in Table C-13. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed. These relationships are also indicated in Table C-13. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table C-13. Key Ecological Attributes (KEA) for the Madrean Encinal and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-3.8 Conceptual Model Diagrams

See Figure C-8 and Figure C-9 above.

C-3.9 References for the CE

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Montane Upland System

Montane Upland System

Lower Montane Woodlands

C-4 Madrean Pinyon-Juniper Woodland

C-4.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Madrean Pinyon-Juniper Woodland (CES305.797)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Madrean Juniper Savanna (CES305.730)
- Madrean Encinal (CES305.795) with scattered PJ

C-4.2 Summary

This evergreen woodland ecosystem occurs on foothills, mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and Arizona, generally south of the Mogollon Rim. Stands are generally restricted to foothill and lower montane elevations ranging from 1460-2225 m with high elevations stands restricted to warmer southern aspects and are found down to 760 m elevation in the Trans-Pecos of Texas (Figure C-10). Sites range from gentle to steep slopes. Substrates are variable, but soils tend to be dry and rocky. Adjacent ecosystems may include and Madrean Encinal (CES305.795) and Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) at higher elevations and Mogollon Chaparral (CES302.741) and Madrean Juniper Savanna (CES305.730) at lower elevations. The environmental description is based on several references, including Brown (1982), Dick-Peddie (1993), Gori and Bate (2007), Gottfried (1992), Muldavin et al. (2000b), and NatureServe Explorer (2013).

Figure C-10. Madrean Pinyon-Juniper Woodland in Arizona (http://azfirescape.org)

Vegetation is characterized by an open to moderately dense tree canopy dominated by pinyon and juniper trees 2-5 m tall (Figure C-10). The presence of pinyons, *Pinus cembroides, Pinus discolor, Pinus remota,* or *Pinus edulis* with Madrean elements in the understory is diagnostic of this ecosystem. *Juniperus coahuilensis, Juniperus deppeana,* and *Juniperus pinchotii* are character species that are often present to dominant. *Pinus edulis* and *Juniperus monosperma* may be the dominants in the northern distribution in combination with Madrean shrub and/or graminoid elements. *Pinus ponderosa* is absent or scattered. Understory layers are variable, ranging from sparse to dense grass or shrub layers. If Madrean tree oak trees such as *Quercus arizonica, Quercus emoryi,* or *Quercus grisea* are present, then they do not dominate tree canopy. Common shrub species may include chaparral, desert scrub or lower montane shrubs such as *Arctostaphylos pungens, Canotia holacantha, Ceanothus greggii, Cercocarpus montanus, Quercus turbinella, Mimosa dysocarpa*, or *Rhus trilobata*. Perennial grasses such as *Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis*, *Muhlenbergia emersleyi*, *Muhlenbergia pauciloba, Piptochaetium fimbriatum,* or *Piptochaetium pringlei* are present in many stands and may form an herbaceous layer. The vegetation description is based on several references, including Brown (1982), Dick-Peddie (1993), Gori and Bate (2007), Gottfried (1992), Muldavin et al. (2000b), and NatureServe Explorer (2013).

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-14. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table C-14. Madrean Pinyon-Juniper Woodland ecological system CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	No Approved ESDs identified	

C-4.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Listed below are TE/SOC/SOI Species Associations: Madrean Encinal Woodland from Coronado National Forest Ecological Sustainability Report USDA-USFS 2009). Pinyon Juniper Woodlands was lumped into Madrean Encinal in the report so both MAR CEs have the same list of species. Some pinyon nut and juniper berry feeders were added to the list from the Natural Dynamics section below as they are important dispersers of these tree species.

Amphibians: Tarahumara Frog (*Lithobates tarahumarae*)

Birds: Elegant Trogon (*Trogon elegans*), pinyon seeds Scrub jays (*Aphelocoma californica*), pinyon jays (*Gymnorhinus cyanocephalus*), Steller's jays (*Cyanocitta stelleri*) and Clark's nutcrackers (*Nucifraga columbiana*)

Mammals: Jaguar (*Panthera onca*); Black Bear (***Ursus americanus***); Arizona Gray Squirrel (***Sciurus arizonensis***), cliff chipmunks (*Neotamias dorsalis*) and rock squirrels (*Spermophilus variegatus*),

Reptiles: New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*); Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*);

Fish: Mexican Stoneroller (*Campostoma ornatum*), Qui chub (*Gila purpurea*) and Yaqui catfish (*Ictaluris pricei*)

Invertebrates: Huachuca Giant Skipper (*Agathymus evansi*), Pygmy Sonorella (*Sonorella micra*) (and many other talussnails)

Vascular Plants: Spreading Marina (*Marina diffusa*); Chiricahua Mock Pennyroyal (*Hedeoma costatum*)

C-4.4 Natural Dynamics

The Nature Conservancy did a review of the Historical Range of Variation for the broader Pinyon-Juniper Woodland (Gori and Bate 2007), however this CE for the MAR is restricted to the pinyon-juniper woodlands found in the Madrean Sky Island Archipelago ecoregion and is better represented by what Moir and Carleton (1987) classified as the High Sun Mild climate zone.

Romme et al. (2003) developed a pinyon-juniper classification with three types based on canopy structure, understory composition, and historic fire regime. All three types: pinyon-juniper grass savanna, pinyon-juniper shrub woodland, and pinyon-juniper forest occur within this ecoregion. However the pinyon-juniper grass savanna and a new, ecologically similar type with tree canopy >10% cover (pinyon-juniper grass open woodland) best represents the Madrean Pinyon-Juniper Woodland ecosystem (Landis and Bailey 2005, Gori and Bate 2007). Other types are the pinyon-juniper shrub woodland, represented by pinyon-juniper trees with an understory of shrubs such as *Quercus turbinella,* and the pinyon-juniper forest type that has a typically sparse understory and is restricted to dry, rocky areas where it is protected from fire (Romme et al. 2003).

Fire dynamics for these types under historic natural conditions (also called natural range of variability, NRV; for pre 1900 time frame), are summarized below based on (Romme et al. 2003).

- The fire regime for the pinyon-juniper grass savanna/pinyon-juniper grass open woodland includes frequent, low-severity surface fires that are carried by the herbaceous layer. The low density of trees (5-20% cover) and high perennial grass cover is maintained by this fire regime. Mean fire interval is estimated to be 12-43 years (Gori and Bate 2007).
- The fire regime for the pinyon-juniper shrub woodland has moderately frequent, high-severity crown fires that are carried by the shrub and tree layers. After a stand replacing fire the site begins at early seral stage and returns to a moderately dense tree layer with a moderate to dense shrub layer. Succession happens relatively quickly if the shrub layer includes chaparral species that recover rapidly from fire by re-sprouting or from fire scarified seeds in a seed bank. Mixed-severity fires may alter this pattern by creating a mosaic of pinyon-juniper states (early, mid, and late seral). Mean fire interval is estimated to be 23-81 years (Gori and Bate 2007)
- The fire regime for the pinyon-juniper forest type has very infrequent, very high-severity fires that are carried by tree crowns. The stand dynamics are stable with multi-age tree canopy and with little change in shrub or herbaceous layers.

Other important ecological processes include climate, drought, insect infestations, pathogens, herbivory and seed dispersal by birds and small mammals.

Climate change has affected the distribution pinyon-juniper woodlands in the past and current climate change will likely shift the geographic and elevational distribution in the future (Betancourt et al. 1993, McAuliffe and Van Devender 1998, Van Devender 1977, Van Devender 1990). For example, after 500 BP, winter precipitation increased and caused a re-expansion of pinyon-juniper woodland that sharply increased after 1700 and again in the early 1900s (Davis and Turner 1986, Mehringer and Wigand 1990, as cited in Gori and Bate 2007). Shorter term variation in climate has important implications for this system. Regional droughts coupled with stress-induced insect outbreaks (pinyon Ips beetle) have caused widespread mortality of pinyons. This affects species dominance patterns, tree age structure, tree density, and canopy cover within pinyon-juniper woodlands and will shift dominance to juniper (Betancourt et al. 1993). Conversely, wet periods create conditions for tree recruitment and growth.

Juniper berries and pinyon nut crops are primarily utilized by birds and small mammals (Balda 1987, Gottfried et al. 1995, Johnsen 1962, McCulloch 1969, Salomonson 1978, Short et al. 1977). Large mammals, mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*) eat leaves and seeds of both species and they browse woodland grasses, forbs and shrubs including *Artemisia tridentata, Cercocarpus montanus, Quercus gambelii,* and *Purshia stansburiana* (Short and McCulloch 1977). The most important dispersers of juniper and pinyon seeds are birds. Juniper seeds that passed through the digestive tract of birds and other herbivores germinate faster than uneaten seeds (Johnsen 1962). The primary dispersers of pinyon seeds, Scrub jays (*Aphelocoma californica*), pinyon jays (*Gymnorhinus cyanocephalus*), Steller's jays (*Cyanocitta stelleri*) and Clark's nutcrackers (*Nucifraga columbiana*), during mast crop years cache hundreds of thousands of pinyon seeds, many of which are never recovered (Balda and Bateman 1971, Ligon 1978, Vander Wall and Balda 1977). In addition, small mammals, like cliff chipmunks (*Neotamias dorsalis*) and rock squirrels (*Spermophilus variegatus*), compete with birds (Christensen and Whitham 1993). There are many insects, pathogens, and plant parasites that attack pinyon and juniper trees (Rogers 1995, Gottfried et al. 1995, Weber et al. 1999). For pinyon, there are at least seven insects, plus a fungus and dwarf-mistletoe (black stain root disease (*Leptographium wageneri*), and pinyon dwarf mistletoe (*Arceuthobium divaricatum*)). These insects are normally present in these woodland stands, and during drought-induced water stress outbreaks may cause local to regional mortality (Gottfried et al 1995, Rogers 1995, Wilson and Tkacz 1992). Most insect-related pinyon mortality in the West is caused by pinyon Ips (*Ips confusus)* (Rogers 1993).

Most pinyon-juniper woodlands in the southwest have high soil erosion potential. Several studies have measured present-day erosion rates in pinyon-juniper woodlands, highlighting the importance of herbaceous cover and cryptogamic soil crusts (Belnap et al. 2001) in minimizing precipitation runoff and soil loss in pinyon-juniper woodlands.

A good condition/proper functioning Madrean Pinyon-Juniper Woodland stand is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions. Soils have not been excessively eroded, and cryptogamic soil crusts are present and undisturbed. The vegetation structure and fire regime that maintains it is functioning at near historical conditions depending on pinyon-juniper woodland types:

- with the pinyon-juniper grass savanna/pinyon-juniper grass open woodland type having frequent fires (FRI 12-43 years), low-severity surface fires that are carried by the abundant herbaceous layer. It has a low density of trees (5-20% cover) and high perennial grass cover is maintained by this fire regime.
- stands of the pinyon-juniper shrub woodland type have moderately frequent, high-severity crown fires that are carried by the shrub and tree layers. After a stand replacing fire the site begin at early seral stage and return to moderately dense tree layer with a moderate to dense shrub layer. Mean fire interval is estimated to be 23-81 years.
- stands of the pinyon-juniper forest type have very infrequent, very high-severity fires that are carried by tree crowns. The stand dynamics are stable with multi-age tree canopy and with little change in shrub or herbaceous layers.

A poor condition/non-functioning Madrean Pinyon-Juniper Woodland ecosystem is highly fragmented, or much reduced in size from its historic extent and the fire regime is functioning outside the historic range of variation. Density of tree canopy is too high and outside the historic range of variation. The surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons. Cryptogamic soil crusts, if present, have been disturbed or destroyed leading to increased soil erosion and loss of topsoil to both wind and water erosional processes.

C-4.4.1 Natural Dynamics Model

Conceptual historic state-and-transition models were developed by a team of ecologists (Gori and Bate 2007) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pinyon-Juniper Woodland. For methods on modeling please see Gori and Bate (2007). We were able to use their models for Madrean Pinyon-Juniper Woodland ecosystem CE because the two types represent the same vegetation. Models for both the pinyon-juniper grass savanna/open woodland and pinyon-juniper shrub woodland are shown (Romme et al. 2003; Figure C-11 and Figure C-12).

Figure C-11. Conceptual state and transition model of historic conditions for the Pinyon-Juniper Savanna vegetation type. This model is from Gori and Bate 2007. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).

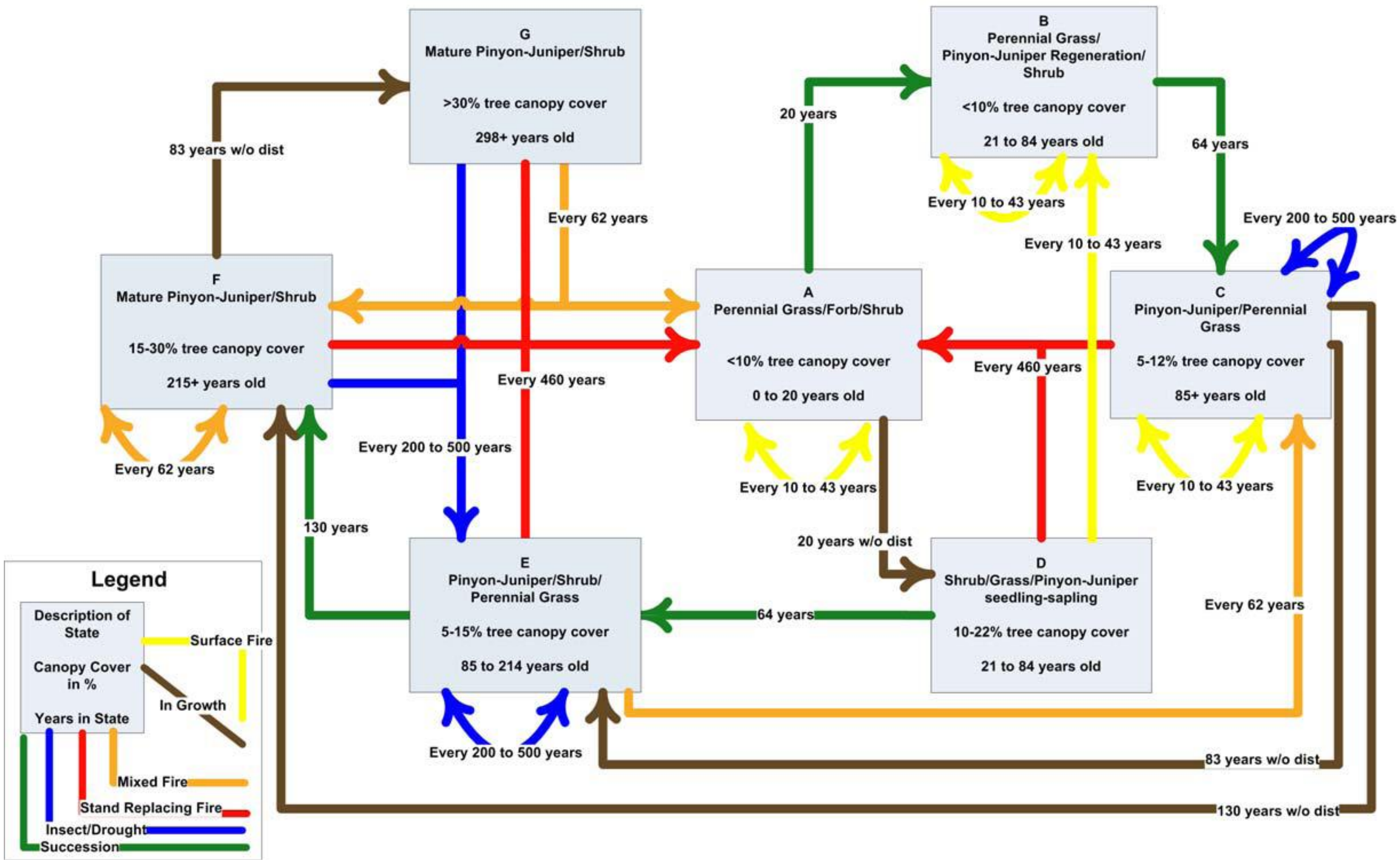
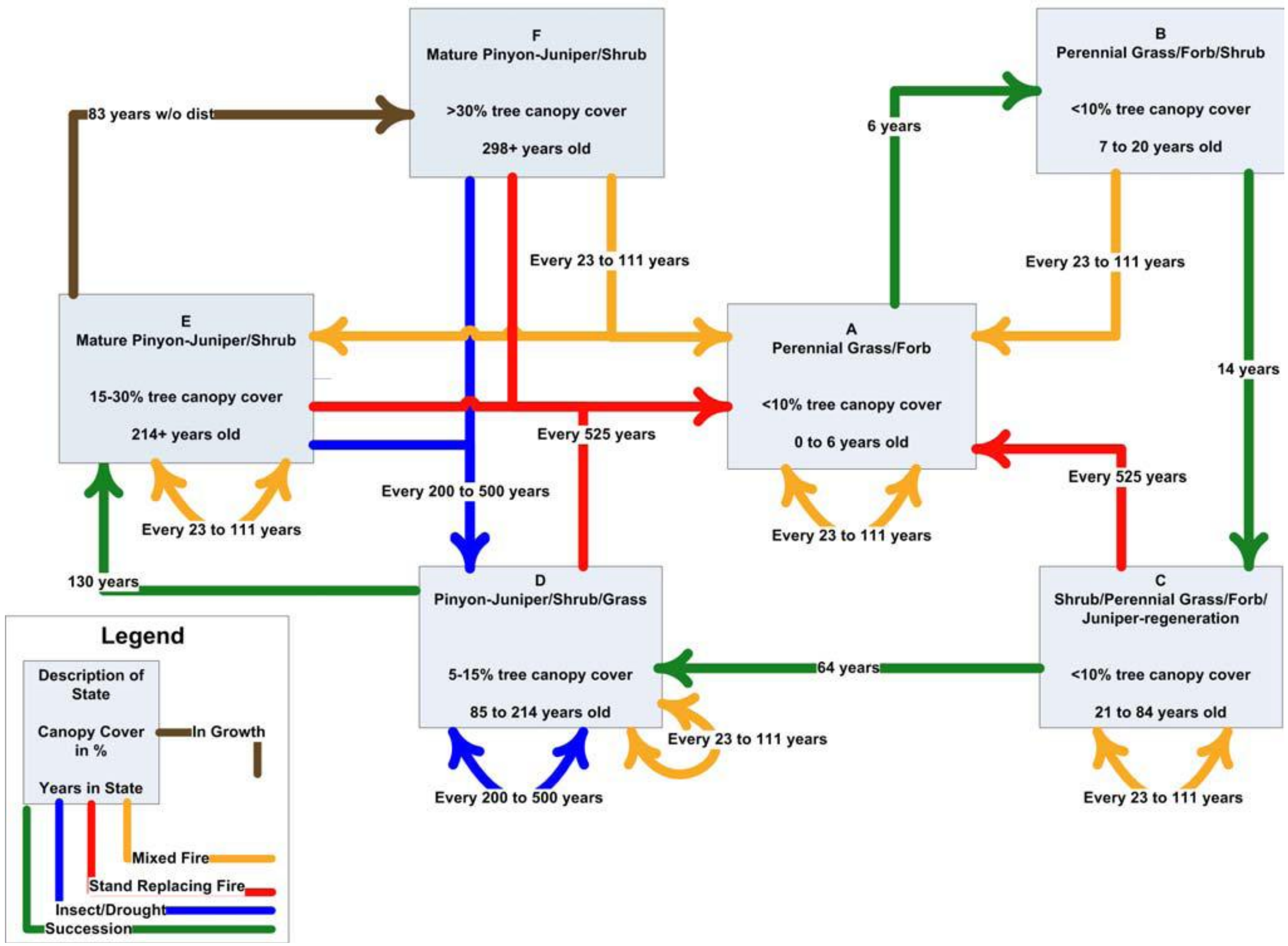


Figure C-12. Conceptual state and transition model of historic conditions for the Pinyon-Juniper Shrub Woodland vegetation type. This model is from Gori and Bate 2007. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation.



C-4.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Pinyon-Juniper Woodland ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-4.5.1 List of Primary Change Agents

Occurrences of this woodland ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table C-15 identifies the most likely impacts associated with each of these stressors.

Table C-15. Stressors and their likely impacts on the Madrean Pinyon-Juniper Woodland ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at inappropriate stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Livestock will trample and destroy osil crusts, leading to soil erosion. Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Romme et al. 2003, Swetnam and Baisan 1996, Swetnam et al. 1999).
Harvesting fuelwood and forest management	Historical fuelwood and fencepost cutting, and, more recently, chemical and mechanical treatments such as chaining and rotochopping, have impacted age structure, tree density and cover of many pinyon-juniper woodlands with current demand for these products continuing to increase (Dick-Peddie 1993a, Gottfried 1987, 1992, Gottfried and Severson 1993, Ffolliot et al 1979). Changes stand structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates addition roads and trails that fragment woodlands and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).

Stressor	Impacts
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Gori and Bate 2007, Heinz Center 2011, Marshall et al. 2004, McPherson 1997).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Gori and Bate 2006).
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes (e.g. fire suppression activities to protect facilities), increased erosion, direct habitat loss/conversion, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, lead to changes in woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Bate 2006, Muldavin et al. 2002; Turner et al. 2003).
Invasive non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*, and annual Bromes (*Bromus* spp.). These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Bate 2006). Post-fire succession may be altered if invasive non-native species colonize and prevent native grasses and forbs from establishing (Floyd et al. 2006).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.

C-4.5.2 Altered Dynamics

The Madrean Pinyon-Juniper Woodland ecological system CE has been impacted by human activities over the last century. Historical fire regimes were disrupted followed the introduction of livestock (and the 1890’s drought). Grazing passively suppresses fire by removing fine fuels needed to carry surface and mixed-severity fires that likely maintained the structure and composition of pinyon-juniper savannas and pinyon-juniper shrub woodlands historically. Active fire suppression was also practiced by the federal government during the last 100 years (Swetnam and Baisan 1996). As fire became less frequent, pinyon and juniper trees became denser and subsequent fires became more severe (Gori and Bate 2007). These impacts altered stand dynamics differently depending on stand structure. Fire dynamics under current conditions are summarized below for the three major pinyon-juniper types (pinyon-juniper grass savanna/open woodland, pinyon-juniper shrub woodland, and pinyon-juniper forest) developed by Romme et al. (2003) using canopy structure, understory composition, and historic fire regime and adapted for our use below.

- The fire regime for the pinyon-juniper grass savanna/ open woodland has a fire frequency that is significantly reduced and fire severity has greatly increased from pre-1900, from low severity surface fires towards high severity and stand-replacing crown fires. Tree density has increased and herbaceous biomass has decreased from historic conditions with active fire suppression and livestock grazing. Currently stands have some very old trees (> 300 years) present but not numerous, but are typically dominated by many young trees (<150 years). This type may also occur on sites with more rock soil and less grasses. This type is outside Historic Range of Variation (HRV) for disturbance regime, structure and composition (Gori and Bate 2007).
- The fire regime for the pinyon-juniper shrub woodland has a fire frequency that is reduced and fire severity is somewhat increased from pre-1900, from low to moderately frequent, high-severity stand replacing fires and moderately frequent mixed severity fires that likely maintain this type, toward less frequent, higher severity fires (Gori and Bate 2007). Tree density has increased and herbaceous biomass has decreased from historic conditions with active fire suppression and livestock grazing. Currently most stands have are a variable mix of tree and shrubs with few or no very old trees (> 300 years) present. With fire suppression, this type may be outside HRV for disturbance regime, and possibly for structure and composition as recent fires are likely more severe than historic fire in late 1800's (Romme et al. 2003).
- The fire regime for the pinyon-juniper forest type still has infrequent, high-severity fires that are carried by tree crowns. The stand dynamics remain relatively stable with little change in density of tree or shrub and herbaceous layers. Currently stands have numerous very old trees (> 300 years) present with a multi-aged structure. Active fire suppression and livestock grazing are thought to have had little impact on fire frequency and severity and the overstory structure and composition with this type remaining within HRV for disturbance regime (Gori and Bate 2007).

Additionally, historical fuelwood and fencepost cutting, and more recently, chemical and mechanical treatments such as chaining and rotochopping, have impacted age structure, tree density and cover of many pinyon-juniper woodlands with current demand for these products continuing to increase (Dick-Peddie 1993a, Gottfried 1987, Gottfried and Severson 1993, Ffolliot et al. 1979).

Fragmentation from a variety of sources such as construction of roads and secondary homes has occurred in many areas of pinyon-juniper woodlands (Gori and Bate 2006).The introduction of non-native annual species as a threat to Madrean Pinyon-Juniper Woodland ecosystem needs to be further investigated (Gori and Bate 2006). It is an important issue in the Great Basin pinyon-juniper woodlands increasing fire frequency and size (Miller and Tausch 2001). In Mesa Verde National Park, invasive non-native species dominate pinyon-juniper woodland areas post-fire (Romme et al. 2003). Post-fire succession may be altered if invasive non-native species colonize and prevent native grasses and forbs from establishing (Floyd et al. 2006).

C-4.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Gori and Bate (2007) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pinyon-Juniper Woodland vegetation type. For methods on modeling please see Gori and Bate (2007). We were able to use their models for Madrean Pinyon-Juniper Woodland ecosystem CE because the two types represent the same vegetation. Models for both the pinyon-juniper grass savanna/open woodland and pinyon-juniper shrub woodland are shown (Romme et al. 2003; Figure C-13 and Figure C-14).

Figure C-13. Conceptual state and transition model of current conditions for the Pinyon-Juniper Savanna/Open Woodland vegetation type. This model is from Gori and Bate 2007. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).

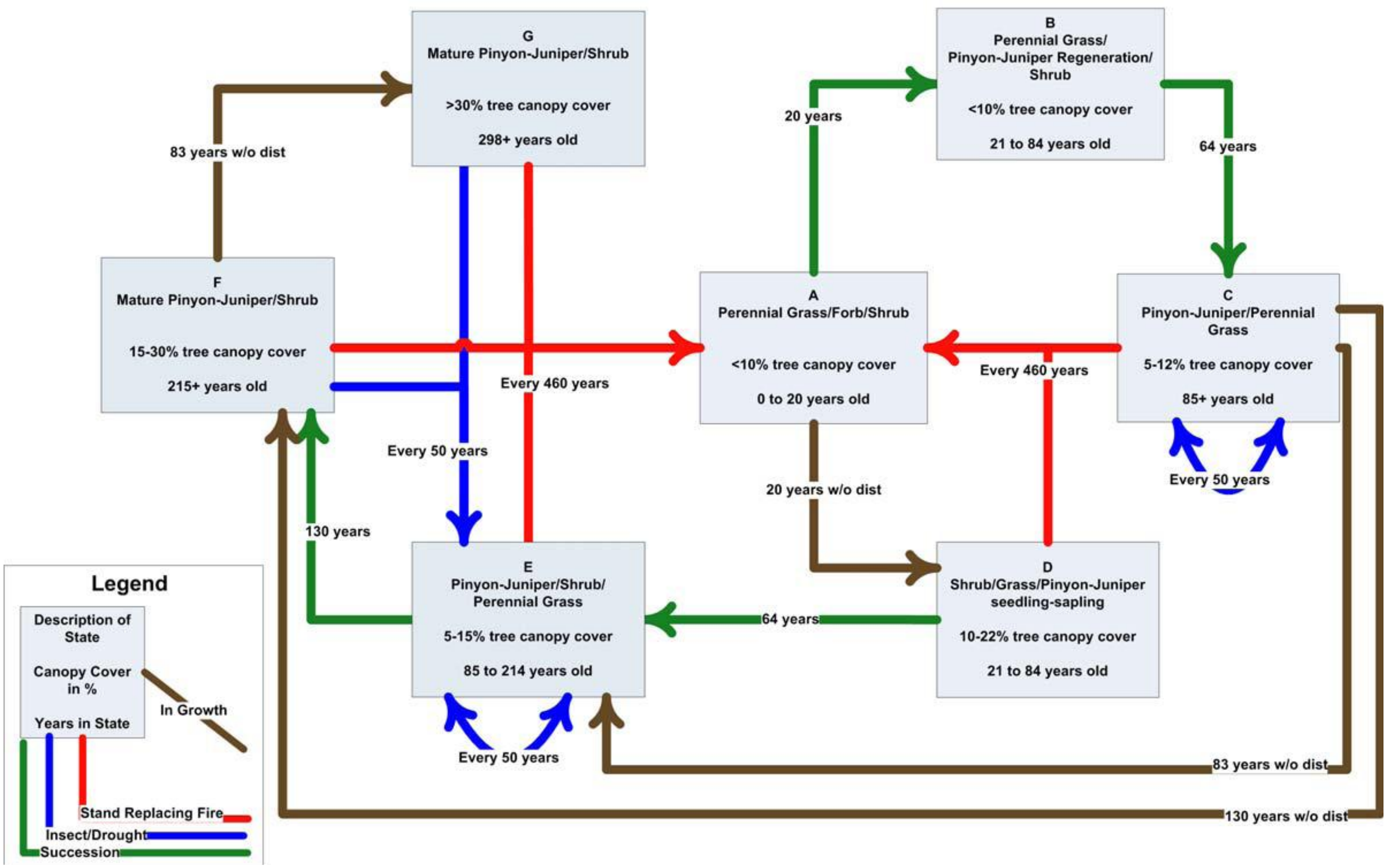
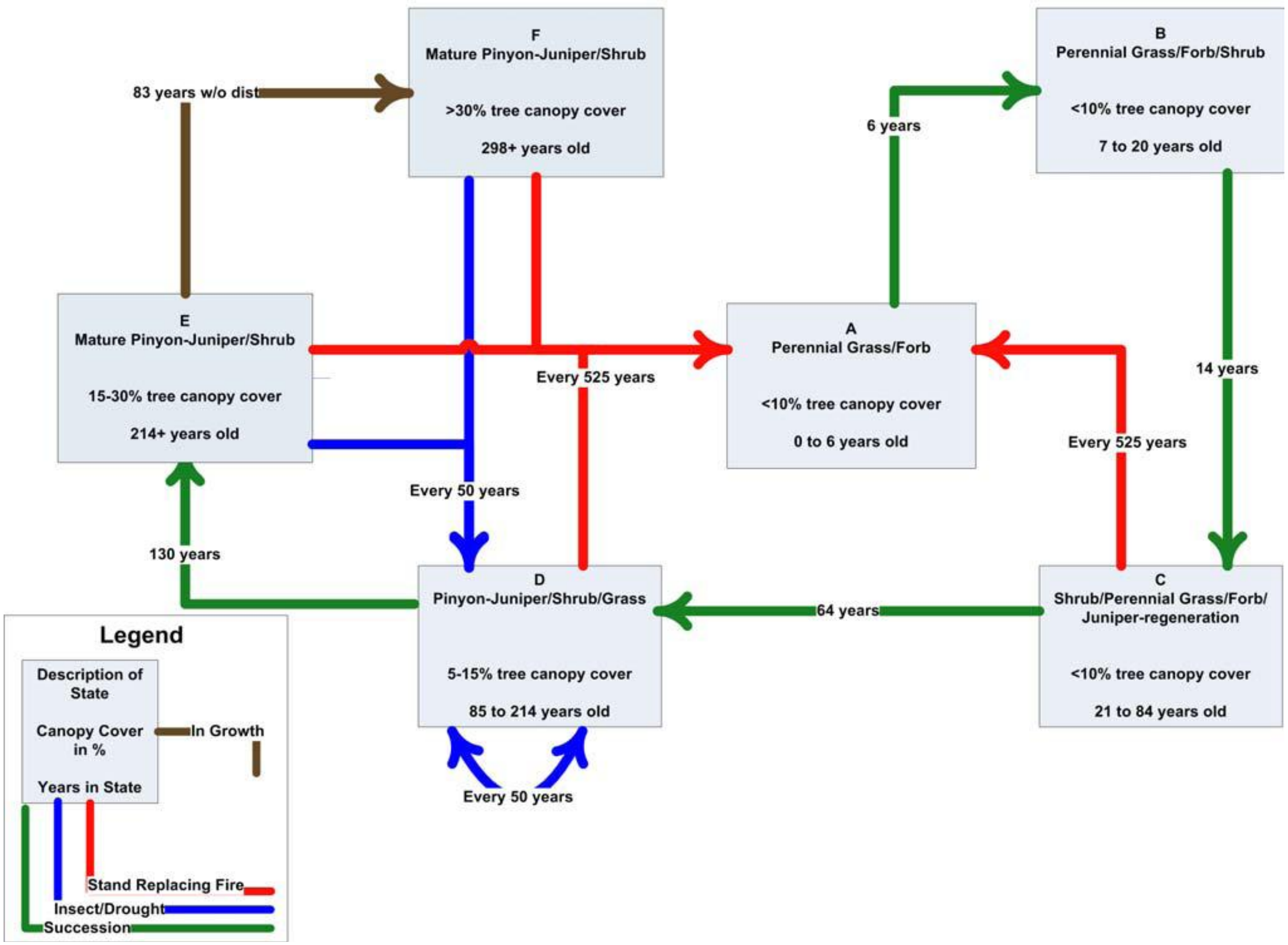


Figure C-14. Conceptual state and transition model of current conditions for the Pinyon-Juniper Shrub Woodland vegetation type. This model is from Gori and Bate 2007. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).



C-4.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-4.6.1 Key Ecological Attributes

Table C-16 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-16. Key Ecological Attributes (KEAs) used to determine the ecological status of Madrean Pinyon-Juniper Woodland ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Ecosystem "Occurrence" Extent	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of shrub or grass understory, soil structure and water infiltration, as well as species diversity. Some plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem. An open tree canopy defines most examples of this CE.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. For example, Gori and Bate (2007) reported increased tree cover and declines in grass cover in these tree savannas and open woodlands with fire suppression. An open tree canopy defines most examples of this CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing sother structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Two of the three types described by Romme et al. (2003) have relatively frequent fires (mean FRI of 12-43 years for the tree savanna – open woodland type with grass understory and mean FRI of 23-81 years for the open woodland with shrub understory (Gori and Bate 2007)). Fire suppression has changed stand structure, and resulted in increased woody cover (tree and shrub) and decreased grass cover. This has lead to very infrequent, very high-severity, stand replacing fires that expose soil to erosion and disrupt other ecological processes (Gori and Bate 2006)	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

C-4.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table C-16 also encompass the four fundamentals of rangeland health (43CFR4180, 2010), as shown in Table C-17. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-17. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table C-17. Key Ecological Attributes (KEA) for the Madrean Pinyon-Juniper Woodland ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-4.8 Conceptual Model Diagrams

See Figure C-11, Figure C-12, Figure C-13, and Figure C-14.

C-4.9 References for the CE

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Montane Shrublands

C-5 Mogollon Chaparral

C-5.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Mogollon Chaparral (CES302.741)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Rocky Mountain Gambel Oak-Mixed Montane Shrubland (CES306.818); possibly in northern extent of MAR
- Rocky Mountain Lower Montane-Foothill Shrubland (CES306.822); possibly in northern extent of MAR
- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735); heavily managed, degraded or seral chaparral might be similar to the grassland system

C-5.2 Summary

This chaparral ecosystem occurs across central Arizona (the Mogollon Rim), western New Mexico, and southern Utah and Nevada (Figure C-15). It often dominates along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into the mountains (1000-2200 m elevation). It occurs on foothills, mountain slopes and canyons in hotter and drier habitats below the oak woodlands (encinal) and *Pinus ponderosa* woodlands. Sites are often associated with more xeric and coarse-textured substrates and are often steep and rocky. Parent materials are varied and include basalt, diabases, gneiss, schist, shales, slates, sandstones and, more commonly, limestone and coarse-textured granitic substrates.

Adjacent ecosystems may include Madrean Pinyon-Juniper Woodland (CES305.797), Madrean Encinal (CES305.795), and Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) at higher elevations and Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735), Chihuahuan Mixed Desert and Thornscrub (CES302.734), Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733), and Madrean Juniper Savanna (CES305.730), at lower elevations. The environmental description is based on several references, including Carmichael et al. 1978, DeBano (1999), Dick-Peddie (1993), Muldavin et al. (2000b), Pase and Brown (1982), Schussman (2006c), and NatureServe Explorer (2013).

The vegetation in this ecosystem is characterized by a moderately to highly dense, evergreen shrub canopy frequently of *Quercus turbinella,* or can be dominated or co-dominated by *Quercus toumeyi, Cercocarpus montanus, Canotia holacantha, Ceanothus greggii, Eriodictyon angustifolium, Garrya flavescens, Garrya wrightii, Mortonia scabrella, Purshia stansburiana, Arctostaphylos pungens* and at higher elevations *Arctostaphylos pringlei*. Additional short shrubs may form a subcanopy such as *Amelanchier utahensis, Coleogyne ramosissima, Ephedra viridis, Dasylirion wheeleri, Rhus ovata,* or *Rhus trilobata* (Pase and Brown 1982, Carmichael et al. 1978). Scattered remnant pinyon and juniper trees may be present. Occasional desert scrub species may be present in drier, rockier, or more open transition sites. Canopy density varies widely depending on time since last fire, soil depth and soil moisture (DeBano 1999). The herbaceous cover is often low or absent because of shading and other factors, but can form a layer composed of *Bouteloua curtipendula, Bouteloua eriopoda,* or *Muhlenbergia pauciflora* especially in the spaces between shrubs in more open stands. Most chaparral species are fire-adapted, resprouting vigorously after burning or producing abundant fire-resistant seeds Stands occurring within montane woodlands are seral and a result of recent fires. The vegetation description is based on several references, including Carmichael et al. 1978, DeBano (1999), Dick-Peddie (1993), Muldavin et al. (2000b), Pase and Brown (1982), Schussman (2006c), and NatureServe Explorer (2013).

Figure C-15. Mogollon Chaparral ecosystem (http://www.azfirescape.org)

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-18. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table C-18. Mogollon Chaparral ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Limestone Hills 16-20" p.z. / *Vauquelinia californica* / *Agave palmeri* - *Cercocarpus montanus* / B*outeloua curtipendula* - T*ridens muticus* (Arizona rosewood / Palmer's century plant - alderleaf mountain mahogany / sideoats grama - slim tridens)	R041XA 103AZ

C-5.3 Species of Conservation or Management Concern

According to Arizona's State Wildlife Action Plan: 2012-2022 (AGFD 2012), "Most wildlife species that occur in chaparral are widespread and common, and Species of Greatest Conservation Need (SGCN) that occupy chaparral also occur in woodland or grassland habitats where chaparral meets those communities at its upper elevation limits, or in desertscrub at lower elevations; examples include

Arizona night lizard *(Xantusia arizonae)*, western red-tailed skink (*Plestiodon gilberti rubricaudata)*, and black-chinned sparrow (*Spizella atrogularis*)."

Reynolds and Johnson (1964) listed 83 species of vertebrates from the chaparral type in Sierra Ancha Experimental Forest, which is the northern extent of the Sky Island Archipelago ecoregion. Below is a short list of vertebrate species from the state wildlife action plan Species of Greatest Conservation Need that Reynolds and Johnson (1964) reported as occurring in chaparral on the Sierra Ancha Experimental Forest in the 1960's. Additionally, the Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009) lists one TE/SOC/SOI species of conservation or management concern that is associated with interior chaparral, the Ball's Monkey Grasshopper (*Eumorsea balli*).

Birds: Montezuma Quail (*Cyrtonyx montezumae*), Elf Owl (*Micrathene whitneyi*), Hooded Oriole (*Icterus cucullatus*),

Mammals: Arizona Gray Squirrel (*Sciurus arizonensis*), Mexican Free-tailed Bat *(Tadarida brasiliensis)*

Reptiles: Gila Monster (*Heloderma suspectum*)

Invertebrates: Ball's Monkey Grasshopper (*Eumorsea balli*).

C-5.4 Natural Dynamics

The Nature Conservancy did a review of the Historical Range of Variation for the Interior Chaparral (Schussman 2006c) and their work relates directly to the Mogollon Chaparral CE and is a primary source for this section. The Mogollon Chaparral ecosystem is complex with diverse species composition and dominance under natural conditions (Carmichael et al. 1978, DeBano 1999, Pase and Brown 1982, Schussman 2006c). Under historic natural conditions (also called natural range of variability, NRV), stands range from open to dense cover of shrubs (depending on time since last stand replacing fire and site variables that restrict shrub growth). This ecosystem appears relatively stable as most dominant shrubs have the ability to recover quickly from fire, either re-sprouting or regenerating from fire scarified seeds (DeBano 1999). Carmichael et al. (1978) suggest that chaparral species' deep, well developed root system facilitates rapid sprouting post fire. In the case of non-sprouting chaparral shrubs such as *Arctostaphylos pringlei* and *Ceanothus* species, the seeds require heat scarification to germinate and will accumulate in the seed bank until a burn treats the seeds and creates a flush of germination (Carmichael et al. 1978). However, too frequent, repeated fires can deplete the seed bank for these species. Additionally, Davis and Dieterich (1976) report that most chaparral only burns well when rate of spread is 20 feet per minute or greater so some wind or slope is necessary for it to burn.

Fire characteristics of interior chaparral are typically medium to high intensity, stand replacing crown fires that occur during summer – fall seasons. They range from medium to very high severity fires that generally top kill most re-sprouting shrubs and kill non-sprouting shrubs (Carmichael et al. 1978, Pase and Brown 1982). Cable (1975) suggests that at least 20 years recovery post-fire is necessary for most stands to burn again. Pase and Brown (1982) suggest a Fire Return Interval between 50-100 years, whereas Wright and Bailey (1982) suggest a FRI of 20-80 years. Based on these sources using a FRI range of 20-100 years seems reasonable.

Herbivory by native herbivores in the Mogollon Chaparral is relatively minor with the exception of mule deer (*Odocoileus hemionus)* and to a lesser extent white-tailed deer (*Odocoileus virginianus)* browsing. Deer eat a variety of forbs, dwarf-shrubs and shrubs (such as *Cercocarpus montanus* and *Garrya wrightii)*, as well as acorns and other fruits (Baker 1999, Cable 1975). Black bears are also key herbivores in interior chaparral and also target acorns and other fruits (Baker 1999). Significant grazing is mostly limited to the more open early seral chaparral stands, as the more common mid to late seral stands have dense canopies with little understory (Cable 1975). Information on invertebrates was not readily available for this CE.

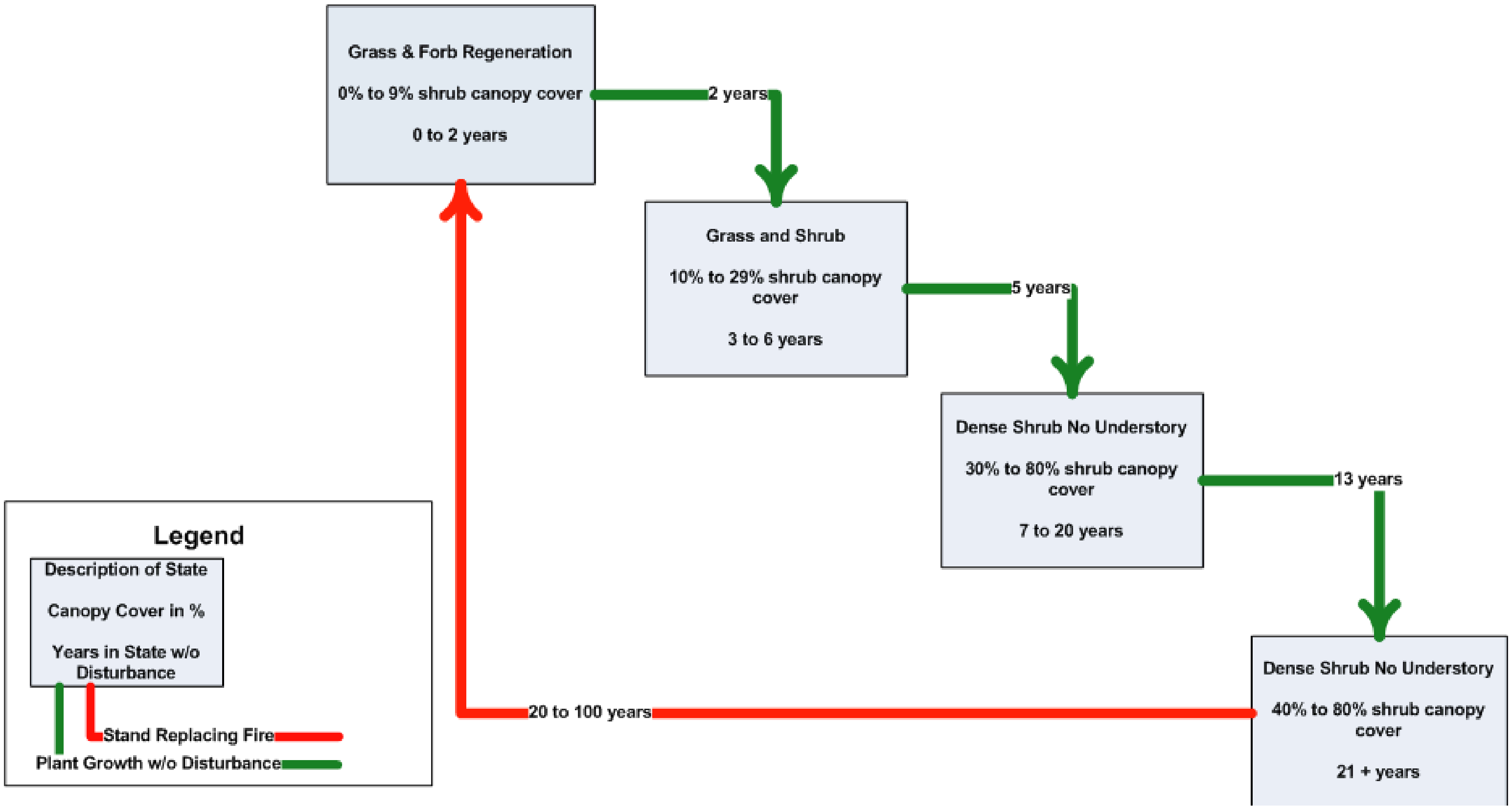
A good condition/proper functioning interior chaparral is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 20 to 100 years; soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, e.g. vegetation composition is altered and lacks non-sprouting chaparral shrubs such as *Arctostaphylos pringlei* and *Ceanothus* species that require occasional fire to cause heat scarification of seed. Highly palatable species such as *Cercocarpus montanus* and *Garrya wrightii*, have been eliminated by excessive browsing by native or non-native species. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons.

C-5.4.1 Natural Dynamics Model

A conceptual historic state-and-transition model was developed by a team of ecologists (Schussman 2006c) using the Vegetation Dynamics Development Tool (VDDT) to model the Interior Chaparral vegetation type. For methods on modeling please see Schussman (2006c). We were able to use their model to represent the Mogollon Chaparral ecosystem CE because the two types represent the same vegetation (Figure C-16).

Figure C-16. Conceptual state and transition model of historic conditions for the Interior Chaparral vegetation type. This model is from Schussman 2006c. Frequency of transitions are noted when this information is supported by published sources, where no or conflicting information exists on the frequency of transitions, unknown is the notation. Note that under the Natural Dynamics model, the FRI for stand replacing fire is 30-100 years (Schussman 2006c).



C-5.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on the Mogollon Chaparral ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-5.5.1 List of Primary Change Agents

Occurrences of this shrubland ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression activities, land development, and non-native plant species invasion. Table C-19 identifies the most likely impacts associated with each of these stressors.

Table C-19. Stressors and their likely impacts on the Mogollon Chaparral ecosystem CE in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock browsing	Browsing of native vegetation by livestock such as goats at inappropriate stocking rates, season of use, or duration can be detrimental and create sacrifice areas as well as degrade forage for native ungulates such as deer (Severson and Debano 1991).
Habitat Conversion to grassland	Habitat conversion to grassland for forage production occurs with repeated prescribed burning. For several years after burning changes in dynamics occur such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989), and increased erosion and stream sedimentation (Heede et al. 1988).
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment occurrences and contribute to increased soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Heinz Center 2011, Marshall et al. 2004).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Gori and Bate 2006).

Stressor	Impacts
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Intensive fire management (both suppression, but more often repeated prescribed burning) causes changes in species composition (Carmichael et al. 1978, Pond and Cable 1960, Schussman 2006c). However, because the natural fire return interval is relatively long for interior chaparral (20-100 years), most stands are still within or near the natural fire return interval even with fire suppression the last one hundred years (Cable 1975, Pase and Brown 1982, USDA-USFS 2009, Wright and Bailey 1982). During the time it takes for chaparral shrub cover to recover post stand replacing fire there are temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989) increased erosion and stream sedimentation (Heede et al. 1988). Fire suppression has led to larger patch sizes and longer fire intervals; however, that is now being coupled with potentially increased frequency of fires and less predictable behavior because of changing weather patterns (i.e. Yarnell fire).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.

C-5.5.2 Altered Dynamics

Altered dynamics are not a large issue with interior chaparral as it is a stable vegetation type with robust ecological dynamics and appears resistant to anthropogenic disturbance. The majority of chaparral species have the ability to quickly re-sprout following disturbance events (Cable 1975, Pond and Cable 1960).

The impact of livestock grazing by cattle is relatively small because cattle use is limited to lower elevation, less steep, and more open slopes (Pase and Brown 1982), and much of this type occurs on steep slopes (Pase and Brown 1982). However, the livestock accessible sites were heavily grazed, between 1880 and 1920 (Pase and Brown 1982).

Additionally, given a natural fire return interval of 20-100 years for interior chaparral, most stands are still within or near the natural fire return interval even with fire suppression the last one hundred years. With continued fire suppression, a reduced abundance of fire dependant obligate seeders such as *Arctostaphylos pringlei* and *Ceanothus* species is predicted because they will be unable to regenerate (Carmichael et al. 1978). These robust ecological dynamics have allowed chaparral to maintain or increase its dense canopy cover regardless of human disturbance. However, fire suppression has led to larger patch sizes and longer fire intervals that is now being coupled with potentially increased frequency of fires and less predictable behavior because of changing weather patterns (i.e. Yarnell fire).

During 1950s-1980s researchers spent 30 years attempting to convert these shrublands to grasslands for forage production for livestock and wildlife, to increase water yield, and reduce fire hazard (Cable 1975).

These efforts were generally unsuccessful (Schussman 2006c). Researchers removed shrubs using prescribed fire and mechanical or chemical treatments, but the effects of the treatments did not last long (Schussman 2006c). Pond and Cable (1960) found that while using repeated burning did not kill the dominant shrub, *Quercus turbinella,* some species such as *Garrya wrightii* and *Rhamnus crocea* were killed after two years of repeated burning, reducing the diversity of the shrub layer.

Seeding of non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula* for forage production after shrub removal did not last as they were shaded out as shrubs re-grew to moderate to dense shrub canopy (Hibbert et al. 1974). So while non-native perennial grasses may be present, they do not dominate areas or effectively change chaparral vegetation or ecological processes as in some other ecosystems, such as the semi-desert grasslands (Hibbert et al. 1974).

Goats were also used in studies to convert shrublands to grasslands. Although goats were effective in reducing shrub cover, they over-used some area creating sacrifice areas and overused the forage most palatable to deer (*Cercocarpus montanus* and *Garrya wrightii*; Severson and DeBano 1991, Knipe 1983). Continued browsing by goats is thought to reduce and eliminate these nutritionally important species making the area unsuitable for both livestock and deer (Severson and DeBano 1991). During the seven or so years for the chaparral shrub cover to recover to pre-treatment levels, researchers also documented temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989), and increased erosion and stream sedimentation (Heede et al. 1988).

C-5.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Schussman (2006c) using the Vegetation Dynamics Development Tool (VDDT) to model the Interior Chaparral native vegetation type. The modelers identified a wide range of mechanical, chemical, and fire treatments for interior chaparral vegetation from multiple studies, conducted primarily within the Tonto National Forest. They decided not to model separate treatments in the regional current model because treatment type was variable and occurred on a relatively small portion of interior chaparral within Arizona and New Mexico. This model includes additional altered states (dominance of Lehman's lovegrass, increased cover of shrubs beyond acceptable ranges, and a degraded eroded state after loss of ground cover) as well as changes in the transitions from the above NRV. For methods on modeling please see Schussman (2006c).

We were able to use this model for Mogollon Chaparral ecosystem CE because the two types represent the same vegetation (Figure C-17 and Figure C-18).

Figure C-17. Conceptual state and transition model of current conditions for the Interior Chaparral vegetation type. This model is from Schussman 2006c. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown or variable, respectively, is the notation. Note that under the Altered Dynamics model, the FRI for stand replacing fire has increased to 500-1000 years because of fire suppression. The treatments include a variety of mechanical, chemical, and fire treatments used on chaparral (Schussman 2006c).

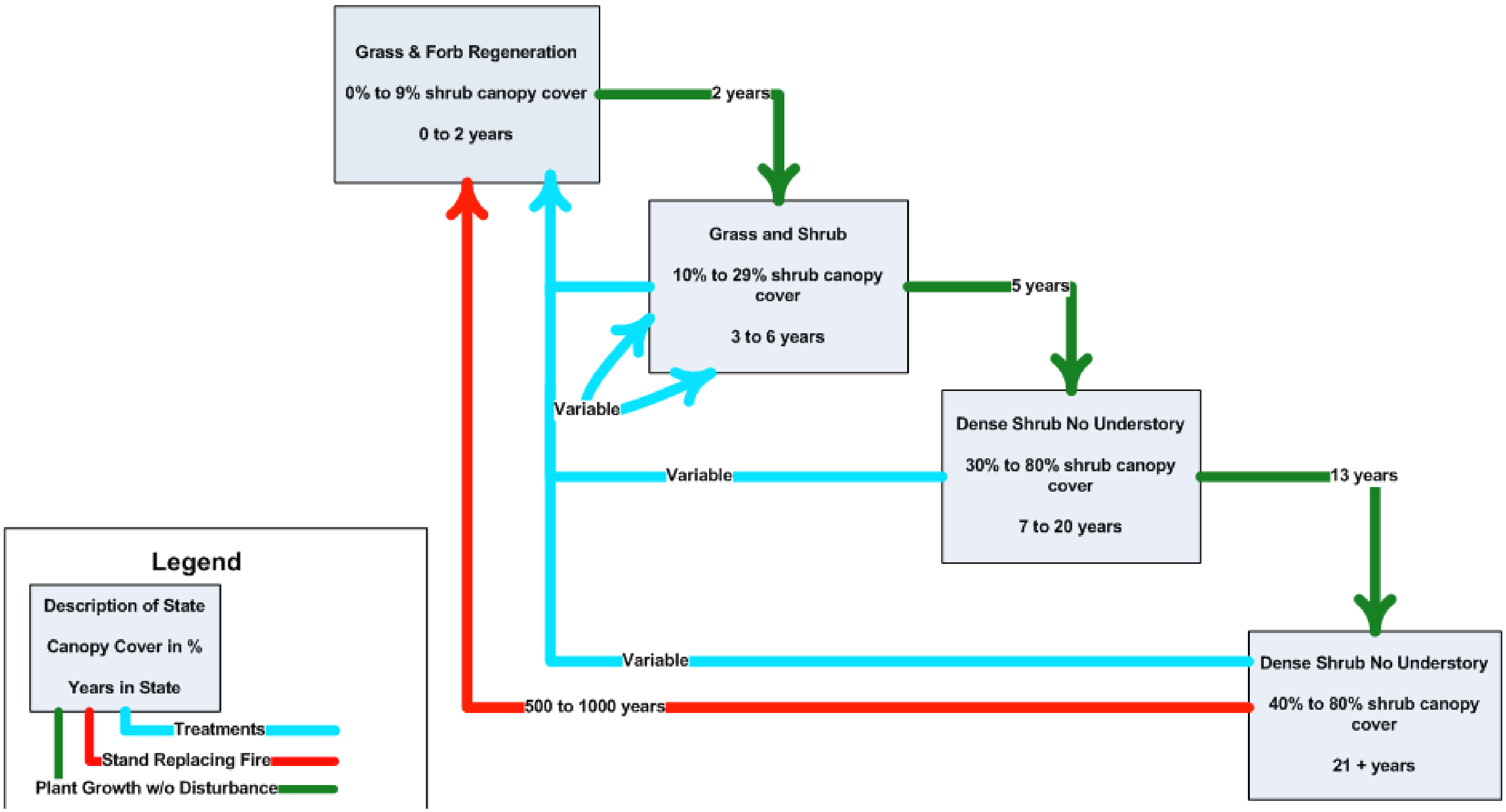
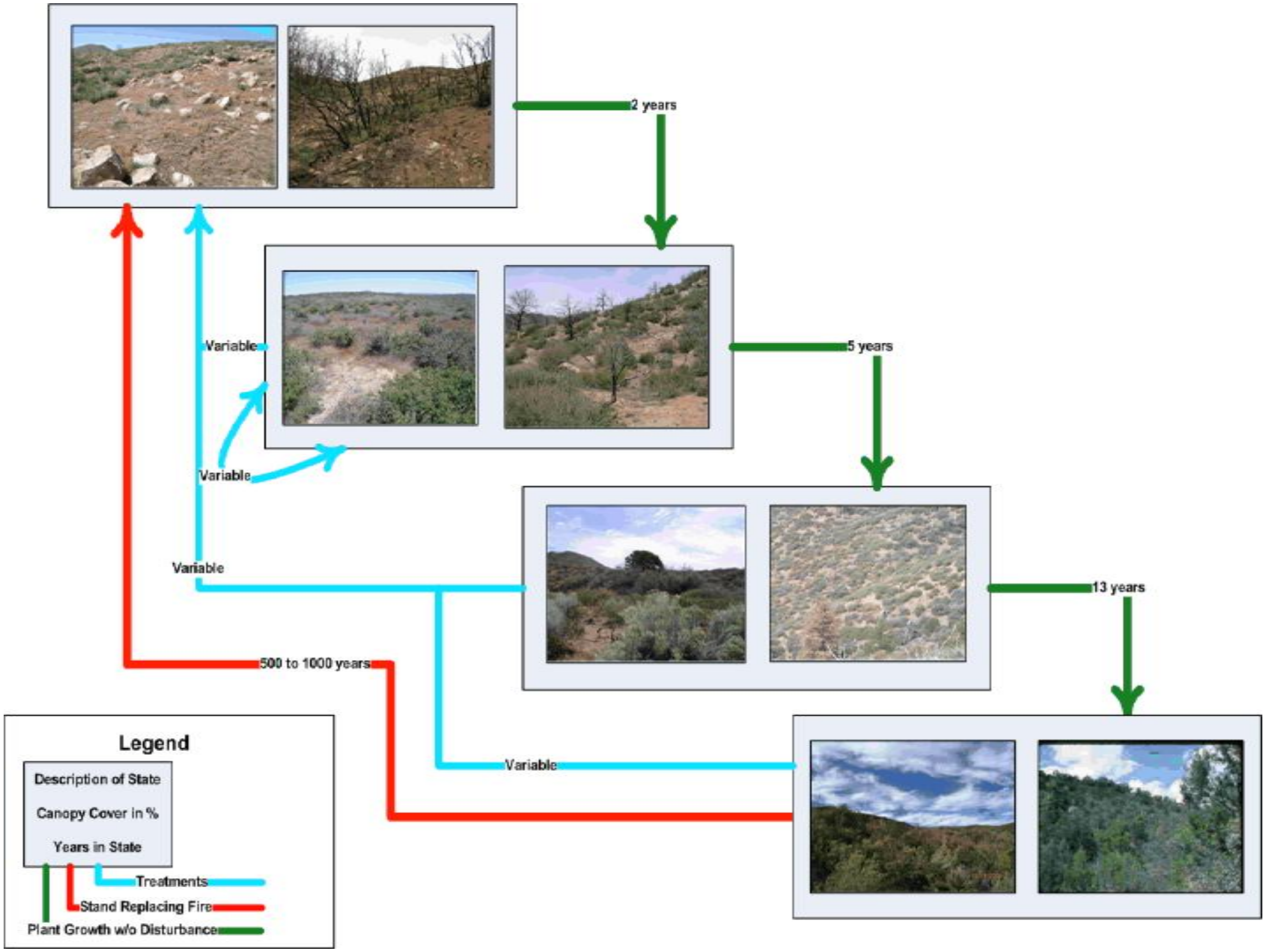


Figure C-18. Photographic depiction of conceptual state and transition model of current conditions for the Interior Chaparral vegetation type This model is from Schussman 2006c. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown or variable, respectively, is the notation. Bottom photographs courtesy of Jeff Saroka (USFS). Note that under the Altered Dynamics model, the FRI for stand replacing fire has increased to 500-1000 years because of fire suppression. The treatments include a variety of mechanical, chemical, and fire treatments used on chaparral (Schussman 2006c).



C-5.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-5.6.1 Key Ecological Attributes

Table C-20 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-20. Key Ecological Attributes (KEA) used to determine the ecological status of Mogollon Chaparral ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Landscape Context:* Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
***Size/Extent:* Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Size/Extent:* Ecosystem "Occurrence" Extent**	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime under the historic range of natural variation for this ecological system needs to be determined.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Pond and Cable (1960) found that using repeated burning did not kill the dominant shrub, Quercus turbinella, but did impact fire dependant obligate seeders such as Arctostaphylos pringlei and Ceanothus spp. (Carmichael et al. 1978) and more fire sensitive species such as Garrya wrightii and Rhamnus crocea reducing the diversity of the shrub layer (Pond and Cable 1960).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An dense canopy of shrubs with low cover of grass vegetation is typical of the Mogollon Chaparral CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing sother structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Intensive fire management (both suppression, but more often repeated prescribed burning) causes changes in species composition (Carmichael et al. 1978, Pond and Cable 1960, Schussman 2006c). During the time it takes for chaparral shrub cover to recover post stand replacing fire there were temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989) increased erosion and stream sedimentation (Heede et al. 1988).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

C-5.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes listed in Table C-20 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-21. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-21. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table C-21. Key Ecological Attributes (KEA) for the Mogollon Chaparral ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-5.8 Conceptual Model Diagrams

See Figure C-16, Figure C-17, and Figure C-18 above.

C-5.9 References for the CE

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Subalpine/Montane Forests & Woodlands

C-6 Madrean Montane Conifer-Oak Forest and Woodland

C-6.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset was chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

Primarily:

- Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796)

- Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798)

In part:

- Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648) or Southern Rocky Mountain Ponderosa Pine Savanna (CES306.649)
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland (CES306.828) in the Pinaleño Mountains.

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Madrean Pinyon-Juniper Woodland (CES305.797)
- Madrean Encinal (CES305.795)

C-6.2 Summary

Madrean Montane Conifer-Oak Forest and Woodland CE is composed of the Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) and the Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798) ecological systems. It also includes any wide ranging *Pinus ponderosa* stands occurring in the MAR (usually classified as part of Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648) or Southern Rocky Mountain Ponderosa Pine Savanna (CES306.649). Stands occur on mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and Arizona, generally south of the Mogollon Rim (Figure C-19).

The lower montane forests and woodlands are composed of Madrean pines (*Pinus arizonica, Pinus engelmannii, Pinus leiophylla*, or *Pinus strobiformis*) and evergreen oaks (*Quercus arizonica, Quercus emoryi*, or *Quercus grisea*) intermingled with patchy shrublands on most mid-elevation slopes (1500-2300 m elevation). Other tree species include *Cupressus arizonica, Juniperus deppeana, Pinus cembroides, Pinus discolor, Pinus ponderosa* (with Madrean pines or oaks), and *Pseudotsuga menziesii*. Subcanopy and shrub layers may include typical encinal and chaparral species such as *Agave* spp., *Arbutus arizonica, Arctostaphylos pringlei, Arctostaphylos pungens, Garrya wrightii, Nolina* spp., *Quercus hypoleucoides, Quercus rugosa*, and *Quercus turbinella*. Some stands have moderate cover of perennial graminoids such as *Muhlenbergia emersleyi, Muhlenbergia longiligula, Muhlenbergia virescens*, and *Schizachyrium cirratum*. Fires are frequent with perhaps more crown fires than in typical ponderosa pine woodlands, which tend to have more frequent surface fires on gentle slopes. Adjacent stands include higher elevation conifer-oak forests (Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798)) and Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Encinal (CES305.797) at lower elevations.

Figure C-19. Madrean Lower Montane Pine-Oak Forest and Woodland in Arizona
(http://azfirescape.org)

The upper montane to subalpine forests (Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798) are confined to the upper elevations in the Sierra Madre Occidentale and Sierra Madre Orientale of Mexico. In the U.S., it is restricted to north and east aspects at high elevations (1980-2440 m) in the Sky Islands (Chiricahua, Huachuca, Pinaleno, Santa Catalina, and Santa Rita mountains, among others) and along the Nantanes Rim. It is more common in Mexico and does not occur north of the Mogollon Rim. These higher elevation stands are characterized by large- and small-patch forests dominated by *Pseudotsuga menziesii, Abies coahuilensis,* or *Abies concolor* with *Pinus strobiformis* often present and Madrean oaks especially *Quercus hypoleucoides* and *Quercus rugosa* at higher elevations as well as *Quercus arizonica, Quercus emoryi, Quercus grisea,* and *Quercus toumeyi*. If *Quercus gambelii* is prominent in the shrub layer, then other Madrean elements are present. This system may include stands of *Quercus gravesii* woodlands. It is similar to Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (CES306.823) which typically lacks Madrean elements.

This CE as defined for the MAR REA also may include small patches of montane mixed conifer and subalpine Engelmann spruce forest at the highest elevations of the larger mountain ranges that are characterized by *Picea engelmanii, Abies lasiocarpa, Abies concolor, Acer grandidentatum, Pinus strobiformis, Pinus flexilis or Pinus ponderosa.* The subalpine forest is essentially limited to the Pinaleño Mountains and is included in the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland

(CES306.828). Adjacent stands include Madrean Pinyon-Juniper Woodland (CES305.797) and encinal Madrean Encinal (CES305.795) at lower elevations and sparse rock outcrop as it is typically the uppermost ecosystem.

This description is based on several references, including Dick-Peddie (1993), Ffolliott and Baker (1999), Moir and Ludwig (1979), Muldavin et al. (1996), NatureServe Explorer (2013), Pase and Brown (1982), Schussman and Gori (2006b), Smith (2006a), Smith (2006b), Smith (2006c) and Stuever and Hayden (1997b).

A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table C-22. (For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table C-22. Madrean Montane Conifer-Oak Forest and Woodland ecological system CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	No Approved ESDs identified	

C-6.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Listed below are TE/SOC/SOI Species Associations from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009) for Madrean Pine-Oak Woodland plus species from Spruce-fir Forest, Mixed Conifer Forest, and Ponderosa Pine Forest, which are included in the concept of this Madrean Montane Conifer-Oak Woodland CE. Also species are listed for montane conifer from both the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006), and the Arizona State Wildlife Action Plan (AZGFD 2012).

Amphibians: Barking Frog ()

Birds: Band-tailed Pigeon (*Patagioenas fasciata*), Mexican Spotted Owl (*Strix occidentalis lucida*), Northern (Apache) Goshawk (*Accipiter gentilis apache*), Lucifer hummingbird (*Calothorax lucifer*); whiskered screech owl (*Otus trichopsis*), Gould's turkey, Montezuma quail (*Cyrtonyx montezumae*), Mexican jay *(Aphelocoma wollweberi),* bridled titmouse (*Baeolophus wollweberi)*.

Mammals: Abert's Squirrel (*Sciurus aberti*); Arizona Gray Squirrel (*Sciurus arizonensis*); Black Bear (*Ursus americanus*); Chiricahua Fox Squirrel (*Sciurus nayaritensis chiricahuae*); Coues' White-tailed Deer (*Odocoileus virginianus couesi*); Elk (*Cervus elaphus*); southern pocket gopher *(Thomomys umbrinus*); and Mt. Graham Red Squirrel (*Tamiasciurus hudsonicus grahamensis*).

Reptiles: Slevin's Bunchgrass Lizard (*Sceloporus slevini*) (in open, grassy stands);Twin-spotted Rattlesnake (*Crotalus pricei*); New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); brown vinesnake (*Oxybelis aeneus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*).

Invertebrates: Arizona Mantleslug (Pallifera pilsbryi); Lichen Grasshopper (Trimerotropis saxatilis) (in rocky areas); Patagonia Eyed Silkmoth (*Automeris patagoniensis*); Pinaleño Monkey Grasshopper

(*Eumorsea pinaleno*); Pinaleño Mountainsnail (*Oreohelix grahamensis*); Pungent Talussnail (*Sonorella odorata*); Cross Snaggletooth (*Gastrocopta quadridens*); Huachuca talussnail, Rosemont talussnail, and many other land mollusks.

Vascular Plants: Catalina Beardtongue (*Penstemon discolor*)(in rocky areas); Chiricahua Gentian (*Gentianella wislizeni*); Chiricahua Mountains Larkspur (*Delphinium andesicola*); Giant-trumpets (*Macromeria viridiflora*); Heliograph Peak Fleabane (*Erigeron heliographis*); Heller's Whitlow-grass (*Draba helleriana var. bifurcata*); Huachuca Mountain Lupine (*Lupinus huachucanus*); Lemmon's Beggar-ticks (*Bidens leptocephala*); Mexican Hemlock-Parsley (*Conioselinum mexicanum*); Mt. Graham Beardtongue (*Penstemon deaveri*); New Mexico Lupine (*Lupinus neomexicanus*); Pinaleño Mountains Rubberweed (*Hymenoxys ambigens*); Purple-spike Coralroot (*Hexalectris warnockii*); Timberland Blue-eyed Grass (*Sisyrinchium longipes*); White-flowered Cinquefoil (*Potentilla albiflora*), and many other plants.

C-6.4 Natural Dynamics

Under historic natural conditions (also called natural range of variability, NRV), the Madrean Montane Conifer-Oak Forest and Woodland ecosystem varied from open woodlands (10-20% cover) with pines dominating the overstory and perennial bunch grass dominating the understory to moderately dense woodlands (20-40% tree cover) with less dense herbaceous layer and more tree and shrub cover. Lower elevation tree line of pines is primarily controlled by dry season water stress (Barton 1993). Fire and drought are the primary disturbances of this ecosystem (USDA-USFS 2009).

Information on fire return intervals is varied depending on elevation zone with fires frequently starting at lower elevations and burning upslope into the montane zone. Lower montane elevation pine-oak stands had frequent, low intensity surface fires (mean fire return every 6-14 years) as a result of lightning ignitions primarily between early spring and summer (Bahre 1985, Kaib et al. 1996, Schussman and Gori 2006, Swetnam and Baisan 1996, Swetnam et al. 1992, Swetnam et al. 2001). However, minimum fire-free periods of 20-30 years are necessary for pines to establish and become resistant (thick bark) to surface fires (Barton et al. 2001). More frequent fire favors oaks and other sprouting species over pines and other conifers, which can alter stand composition. Less frequent fire (FRI >50 years) results in more conifer recruitment and denser vegetation that can lead to higher intensity, mixed severity and patches of stand replacing fires that also favors oaks and other sprouting species (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006).

For the inclusions of Ponderosa Pine Woodland in the Madrean Conifer-Oak Forest and Woodland the historic mean fire return interval is similar (Smith 2006a). In Arizona and New Mexico, Swetnam and Baisan (1996) found the historic mean fire return interval ranges from 2 to 17 years for fires scarring one or more trees, and 4 to 36 years for fires scarring between 10% and 25% of trees between the years of 1700 and 1900. However in the more mesic subalpine fir communities a fire return interval of up to 400 years is not uncommon.

Herbivory by native herbivores in the Madrean montane conifer-oak forests and woodlands is variable in this type. For more open stands with grass-dominated understory herbivores are similar to semi-desert grasslands. Large herbivores include browsers like Coues' white-tailed deer (*Odocoileus virginianus couesi*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and rodents such as yellow nosed cotton rat (*Sigmodon ochrognathus*), whitethroated wood rat (*Neotoma albigula*), southern pocket gopher (*Thomomys umbrinus*), Apache squirrel (*Sciurus nayaritensis*), Arizona gray squirrel (*Sciurus arizonensis*), porcupine (*Erethizon dorsatum*), Bailey's pocket mouse (*Chaetodipus baileyi*), and eastern cotton tail (*Sylvilagus floridanus*) are common in the Madrean pine-oak woodlands (Majkael al. 2007, Schussman and Gori 2006). Southwestern forest trees have been host to several species of insects, pathogenic fungi, and parasitic plants, however there are no accounts of historic insect outbreak, fungi or parasitic plant periodicity (Dahms and Geils 1997).

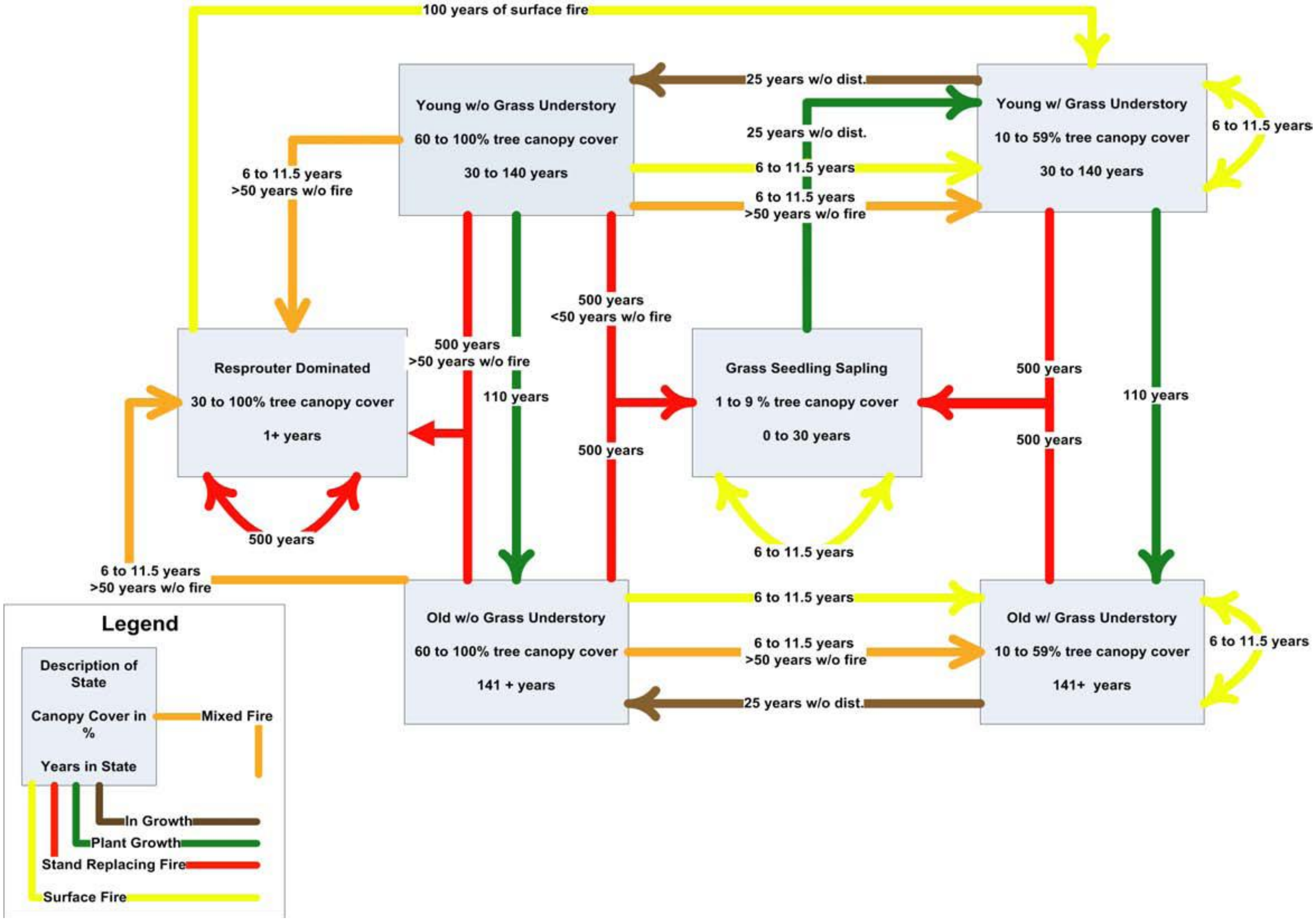
A good condition/proper functioning occurrence of Madrean Montane Conifer-Oak Forest and Woodland ecosystem is large and uninterrupted; the surrounding landscape is also in good condition with soils that have not been excessively eroded. The biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions. There is a diversity of stand age and size classes in response to a functioning natural fire regime. For the majority of the type (lower montane pine-oak woodlands) that is frequent (mean fire return every 6-14 years), low intensity surface fires with occasional fire free periods of 20-30 years minimum to allow for conifers to establish and become resistant (thick bark) to surface fires. For upper montane conifer oak and mixed conifer forests, the historical fire regime would have less frequent fires, mixed severity and occasional stand replacing fires. The subalpine spruce forest only rarely burns but has high severity, stand replacing fires under extreme fire conditions.

A poor condition/non-functioning occurrence is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to exurban development; the biotic condition is at the limit or beyond natural range of variation. The montane conifer-oak woodland and forest stands would have high density of trees and excessive fuel loading from passive (livestock grazing) and active fire suppression. Characteristic birds, mammals, reptiles, and insects and amphibian species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations.

C-6.4.1 Natural Dynamics Model

A conceptual historic state-and-transition model was developed by a team of ecologists (Schussman and Gori 2006) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pine-Oak Woodland. For methods on modeling please see Schussman and Gori (2006) (Figure C-20). This is the primary forest type of the CE. For models of other montane forest and woodland types treated as inclusions in this CE, please refer to Smith (2006a, 2006b, 2006c).

Figure C-20. Conceptual state and transition model of historic conditions for the Madrean Pine Oak Woodland vegetation type. This model is from Schussman and Gori 2006. Frequency of transitions are noted (Schussman and Gori 2006).



C-6.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Montane Conifer-Oak Forest and Woodland ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-6.5.1 List of Primary Change Agents

Occurrences of this woodland and forest ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression, land development, recreation, and non-native plant species invasion. Table C-23 identifies the most likely impacts associated with each of these stressors.

Table C-23. Stressors and their likely impacts on the Madrean Montane Conifer-Oak Forest and Woodland ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livesotck grazing	Grazing of native vegetation by livestock at inappropriate stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Kaib et al. 1996; Swetnam and Baisan 1996).
Harvesting of fuelwood; silviculture	Fuel wood cutting has impacted stands in southeastern Arizona historically and is still common for domestic use (Bahre 1991, Bennet 1992). Logging has also occurred. Changes stand structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment woodlands and increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).

Stressor	Impacts
Energy (Renewable wind/solar), Oil/Gas	While unlikely to be common in these montane areas, this stress contributes to altered fire regimes (e.g. protection of facilities), increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, lead to changes in woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003). Insect outbreaks in forests also affect fire regime.
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil. Climate change has also affected insect and disease outbreak in forests.

C-6.5.2 Altered Dynamics

Madrean Montane Conifer-Oak Forest and Woodland stands have been impacted by fragmentation, silviculture, fire management, and livestock grazing over the last century. The lower montane woodlands are characterized by a strong perennial grass layer and are driven by many of the same ecological processes as encinal, primarily fire and grazing. The upper montane forests have less forage available and are less impacted by livestock but more impacted by logging and active fire suppression. Fragmentation of landscape can impact the movement of fires that start in lower elevation savannas and woodlands and burn upslope into the montane zones.

It is generally agreed that the fire regime has been altered for Montane Conifer-Oak Forest and Woodland *by passive fire suppression* via removal of fine fuels through livestock grazing, as well as active suppression over the last 100 years. This has reduced the number of fires and increased fire severity in conifer-oak forests and woodlands and adjacent vegetation types like encinal across much of the southwestern US and adjacent Mexico (Kaib et al. 1996, Swetnam and Baisan 1996).

Structurally as tree canopy becomes denser the cover of shade-intolerant grass understory is eliminated and replaced with shade tolerant shrubs or no understory when tree canopy closes. The Coronado National Forest Assessment (USDA-USFS 2009) shows a large forest structural class shift from historic natural or reference conditions to current conditions for two montane forest types. The Madrean Pine Oak Woodland shows the largest declines in young pine without oak in understory (grassy) and old pine-oak woodlands with understory to old pine-oak woodlands without understory (Table C-24).

Table C-24. Reference and Current Conditions: Madrean Pine Oak Woodland on the Coronado National Forest (from USDA-USFS 2009).

Structural Class	Reference	Current
Grass, seedling, saplings	4%	9%
Young pine oak w/o understory	3%	12%
Young pine oak w/understory	24%	5%

Old pine oak w/understory	60%	10%
Old pine oak w/o understory	4%	64%
Resprouter dominated	5%	0%

Ponderosa pine structural classes for historic (reference) and current conditions have also shifted in the Coronado National Forest and are displayed below (Table C-25). There has been a major shift from open tree canopy (<30% cover) old forest with regeneration to mid-aged, mature and old forest with closed tree canopy (>30% cover). These changes in tree canopy density have increased risk from uncharacteristically large insect outbreaks and destruction by unnaturally large and intense wildfires (USDA-USFS. 2009).

Table C-25. Reference and Current Conditions: Ponderosa Pine Woodland on the Coronado National Forest (from USDA-USFS 2009). The distribution of Ponderosa pine structural classes for historic (reference) and current conditions is displayed below.

Structural Class	Reference	Current
Open forest states (Canopy closure <30%)		
Grass, seedling, saplings	0%	1%
Young forest	0%	4%
Mid-aged forest	<1%	6%
Mature forest	<1%	<1%
Old forest with regeneration	99%	<1%
Closed forest states (Canopy closure >30%)		
Grass, seedling, saplings	0%	1%
Young forest	0%	7%
Mid-aged forest	0%	47%
Mature and old forest	0%	32%

This altered fire regime or uncharacteristic fire has large effects on the tree canopy and understory vegetation structure of these woodlands. The increased density of woody species in the Madrean Montane Conifer-Oak Forest and Woodland has changed the fire regime to more mixed severity and stand replacing fires when fires occur (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006a, Smith 2006a, USDA-USFS 2009).

In addition, species composition is also affected by fire regime as more frequent fire favors oaks and other sprouting species over pines and other conifers, and less frequent fire (FRI >50 years) results in more conifer recruitment (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006).

Fuel wood cutting for mining and domestic use was common in Madrean conifer-oak forest and woodland in southeastern Arizona until the late 1800's, and is still common in Arizona and northern Mexico today (Bahre 1991, Bennet 1992). Although fuel wood harvesting had a dramatic effect historically its consequences were generally local and short-lived (Turner et al. 2003). Logging has also impacted stands in this ecosystem.

Madrean conifer-oak forest and woodlands have been altered through road construction, exotic species introductions, logging, and fire suppression, contributing to what has been called the "no analogue" condition: the current evolutionary environment may be different from the historic evolutionary environment, and some historical conditions may be neither attainable nor desirable as management goals (Swetnam et al. 1999).

Fragmentation has a large impact especially around urban areas and has increased greatly in the last 70 years (Bahre 1991). It has been well documented as an ecological stressor and threat in many assessments and reports (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b). Urban development has lead to the loss and fragmentation many vegetation types and the alteration of ecological processes, such as fire, that use to maintain the vegetation with home, road and fence building (Bahre 1991, Finch 2004, McPherson 1997). In addition, roads are vectors for the spread of invasive non-native plant seeds, and for wildlife species, road kill increases, migration routes and home ranges are altered, and dispersal ability is compromised (USDA 2009).

C-6.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Schussman and Gori 2006) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pine-Oak Woodland. Results are displayed below in two figures, one with the name of the different states in the boxes and one with representative pictures (Figure C-21 and Figure C-22). For methods on modeling please see Schussman and Gori (2006). This is the primary forest type of the CE. For models of other montane forest and woodland types treated as inclusions in this CE, please refer to Smith (2006a, 2006b, 2006c).

Figure C-21. Conceptual state and transition model of current conditions for the Madrean Pine Oak Woodland vegetation type. This model is from Schussman and Gori 2006. Frequency of transitions are noted (Schussman and Gori 2006).

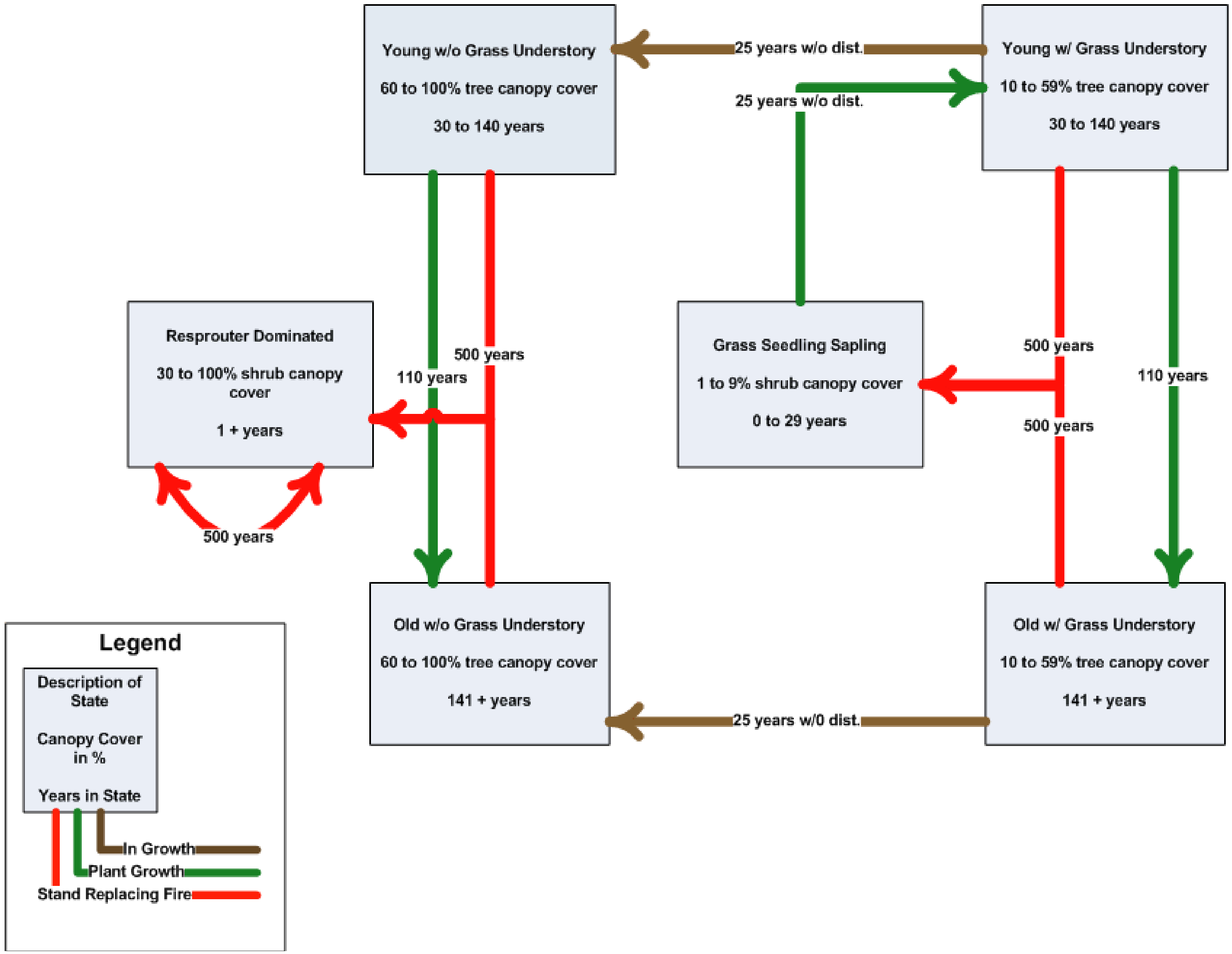
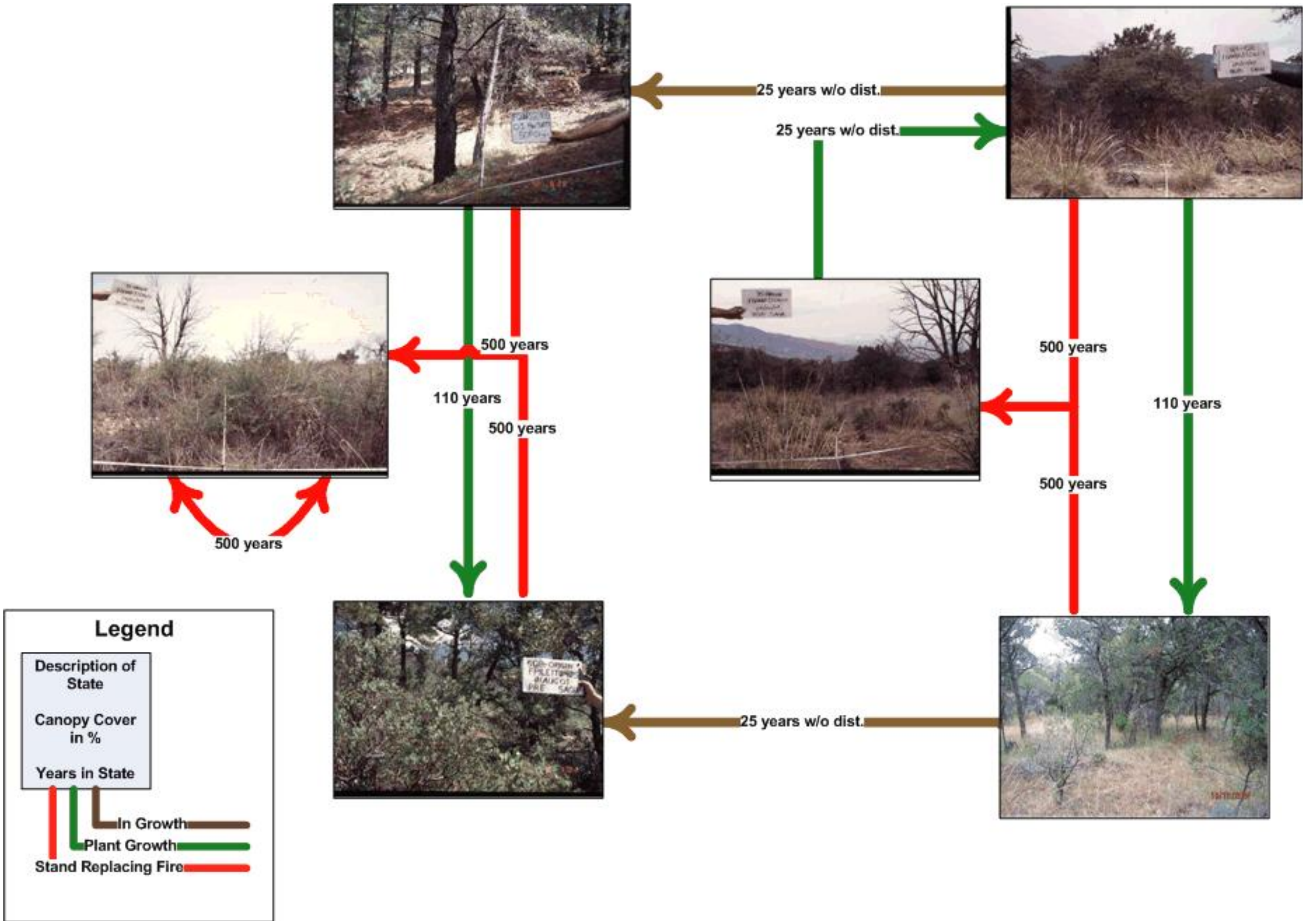


Figure C-22. Photographic depiction of conceptual state and transition model of current conditions for the Madrean Pine-Oak Woodland vegetation type. This model is from Schussman and Gori 2006. Frequency of transitions are noted. Photographs courtesy of James Leckie (Saguaro National Park) and Coronado National Forest (Schussman and Gori 2006).



C-6.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-6.6.1 Key Ecological Attributes

Table C-26 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-26. Key Ecological Attributes (KEA) used to determine the ecological status of Madrean Montane Conifer-Oak Forest and Woodland ecosystem CE in the Madrean Archipelago ecoregion.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historic patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historic range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire reqime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of shrub and herbaceous layers, soil structure and water infiltration, as well as species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Kaib et al. 1996, Swetnam and Baisan 1996).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open to closed conifer & oak tree canopy with low to moderate cover of native perennial grass defines Madrean Conifer-Oak Forest and Woodland CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggreagates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing sother structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes (Barton 1999, Muldavin et al. 2002, Turner et al. 2003). For Madrean Conifer-Oak Forest and Woodland, low intensity surface fire (mean FRI of 6-14 years) with occasional fire free periods of 20-30 years are necessary for pines to establish and become resistant (thick bark) to surface fires and is key to maintaining these forests and woodlands (Bahre 1985, Barton et al. 2001, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

C-6.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table C-26 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-27. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-27. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table C-27. Key Ecological Attributes (KEA) for the Madrean Montane Conifer-Oak Forest and Woodland, and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

C-6.8 Conceptual Model Diagrams

See Figure C-20, Figure C-21, and Figure C-22.

C-6.9 References for the CE

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Aquatic/Wetland/Riparian Ecological System Conceptual Models

Connected Stream and Wetland System

Basin River and Riparian

C-7 North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream

C-7.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)
- North American Warm Desert Riparian Mesquite Bosque (CES302.752)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES302.747)
- North American Warm Desert Cienega (CES302.747)
- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)

C-7.2 Summary

This ecological system consists of riparian corridors and perennial and seasonally-flowing streams (Figure C-23) along canyons and across desert valleys generally at low-elevations (< 1200 m, ~4000 ft)[1] with variation due to hydrogeologic setting, found in southwestern United States and adjacent Mexico (Comer et al. 2003) Mesquite-dominated sites can also occur along intermittent streams, where higher groundwater levels permit. The vegetation is a mix of riparian woodlands and shrublands. Dominant native trees include *Acer negundo, Fraxinus velutina, Populus fremontii, Prosopis glandulosa, Prosopis velutina, Salix gooddingii, Salix lasiolepis, Celtis laevigata var. reticulata, Platanus racemosa*, and *Juglans major*. Native shrub dominants include *Baccharis salicifolia, Pluchea sericea, Salix geyeriana, Shepherdia argentea*, and *Salix exigua* (Comer et al. 2003, Robinett 2005b, Stromberg et al. 2009).

This ecosystem covers woody vegetated riparian areas typical of the Sandy Bottom Ecological Site Description (Robinett 2005b). This CE does not include the Loamy Bottom Ecological Site where giant sacaton (*Sporobolus wrightii*) dominates, as described by NRCS (Wright 2002, Robinett 2005a) and Stromberg et al. (2009). Giant sacaton stands may be adjacent to woody riparian ecosystems.

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[1] Tentative proposed elevation-break, specific to the MAR

Figure C-23. Photos of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream of the San Pedro River, AZ.

The aquatic fauna and flora vary depending on flow characteristics: perennial or intermittent; the frequency, intensity, seasonal timing, and duration of high-flow pulses, low-flows, and dry conditions; the relative contributions of rainfall/runoff and groundwater discharges to flow, including discharges from discrete springs; water temperature and chemistry; channel substrate and form, including the distribution of shaded pools; the extent of the hyporheic zone; and drainage network connectivity.

As with all warm desert streams and rivers, this ecosystem supports a unique range of aquatic species adapted to the overall scarcity and irregular availability of water over space and time, and the frequent isolation of perennial reaches by dry conditions across the rest of the drainage network. These factors result in a high degree of endemism among the aquatic biota, including species adapted to using pools or the hyporheic zone as their main habitat or as refuge during periods with low, intermittent, or no flow.

These factors select for a unique spectrum of aquatic species in this ecosystem. For example, benthic macroinvertebrate assemblages generally consist of highly tolerant, short-lived, fast-reproducing individuals with broad ecological tolerances, with an emphasis on collectors/gatherers and grazers. Vertebrate and invertebrate species able to use the hyporheic zone as their main habitat or as a refuge during periods without flow or during extreme flow pulses occur in this system type (e.g., Del Rosario and Resh 2000, Levick et al. 2008), as do aquatic species tolerant of higher water temperatures and salinity. Disturbances caused by intermittent flows may actually facilitate high food quality and consequently high levels of insect production (Fisher and Gray 1983, Jackson and Fisher 1986, Grimm and Fisher 1989, Huryn and Wallace 2000).

C-7.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. Sources include the Gila Ecoregion in Freshwater Ecoregions of North America (Abell et al. 2000), and Stefferud et al. (2009).

Reptiles and Amphibians: Mexican garter snake, lowland leopard frog.

Birds: Gray hawk, yellow-billed cuckoo, Southwestern Willow Flycatcher (*Empidonax trailii extimus*), and many other migratory and breeding species.

Fish: Spikedace (*Meda fulgida*) (Gila R), loach minnow (*Tiaroga cobitis*) (Gila & San Francisco R.), Gila trout (*Salmo gilae*), Long fin dace (*Agosia chrysogaster*) and Gila topminnow (*Poeciliopsis occidentalis*) endemic to Gila R., Gila chub (*Gila intermedia*), Colorado Squawfish (*Ptychocheilus *lucius*) and Razorback sucker (*Xyrauchen texanus*) endemic to Colorado River Basin may once have been in the Gila R., and Roundtail chub (*Gila robusta*) Gila R. Additional fishes include the Sonora sucker (*Catostomas insignis*) and the Desert Sucker (*Pantosteus clarki*)

Mammals: Beaver (*Castor canadensis*)

C-7.4 Natural Dynamics

The hydrologic regime of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem is naturally highly variable temporally and spatially among the streams of this ecosystem.

Faunal and floral composition and dynamics – both terrestrial and aquatic – are shaped by episodic flooding and associated sediment scour and deposition, and by the rise and fall of the alluvial water table. Vegetation is relatively dense, especially when compared to drier washes. Woody vegetation, especially the mesquites, cottonwoods, and willows, rely on groundwater recharged to the alluvial soils either by seasonal runoff along the channel or by deeper groundwater connections. In turn vegetation can affect the velocity of surface flows (Stromberg et al. 2009, Noonan 2013).Locally, bedrock formations may force groundwater to the surface – either along diffuse gaining reaches or at discrete springs – where it supports the alluvial water table and channel baseflow that are unaffected by precipitation event runoff. Historically, areas of surface water-groundwater connection sometimes supported extensive open wetland complexes without significant woody vegetation (e.g., Stromberg et al. 1996, Stromberg 1998, USFWS 1999, Shafroth et al. 2000, Snyder and Williams 2000, Horton et al. 2001, Stromberg 2001, Eby et al. 2003, Calamusso 2005, Lite and Stromberg 2005, Stromberg et al. 2005, Leenhouts et al. 2006, Stromberg et al. 2006, Webb and Leake 2006, Stromberg et al. 2007, Propst et al. 2008, Katz et al. 2009, Shafroth et al. 2010).

Except at locations and times where groundwater discharge occurs, stream depth and discharge vary widely in where they occur, at what magnitudes, and when and how often, as a result of the wide variation in where and when precipitation takes place (e.g., Abell et al. 2000, Stromberg 2001, Eby et al. 2003, Stromberg et al. 2007, Shafroth et al. 2010). Intense runoff is highly erosive, resulting in rapid reconfiguration of aquatic and riparian macrohabitats, particularly along reaches with sand and gravel substrates. As a result of this intense regime of fluvial disturbance, occurrences of this ecosystem often contain a mix of early-, mid- and late-seral riparian plant associations. They may also contain non-obligate riparian species. Mesquite is a phreatophyte and can tolerate significant drops in the water table in low-flow years. Cottonwood communities are early-, mid- or late-seral, depending on the age-class of the trees and the associated species of the occurrence (Kittel et al. 1999b). Cottonwoods, however, do not reach a climax stage as defined by Daubenmire (1952). Mature cottonwood occurrences do not regenerate in place, but regenerate by "moving" up and down a river reach. Over time, a healthy riparian area supports all stages of cottonwood communities (Kittel et al. 1999b).

This riparian and aquatic ecosystem has high spatial and temporal variation that is driven by many abiotic factors. The timing, duration, temperature range of perennial flow (from groundwater dynamics) and flow pulses (from watershed runoff) - are shaped by the warm, arid climate with extreme contrast between daytime and nighttime temperatures. Spatial extent of perennial flow is controlled by the distribution of bedrock canyons and sills that force alluvial groundwater flow to the surface, by the distribution of buried channel gravels, and by the distribution of springs from deeper aquifers with sufficient discharge to support streamflow. The limited precipitation is concentrated at higher elevations mostly as rainfall but sometimes also as snow, and substantial precipitation and/or snowmelt events are necessary to produce runoff that reaches the low-elevation occurrences of this ecosystem (e.g., Price et al. 2005).

The presence and magnitude of such runoff events vary greatly from season to season, year to year, and decade to decade (e.g., Price et al. 2005, Serrat-Capdevila et al. 2007). The Madrean Archipelago ecoregion is the northern and western most arm of the Chihuahuan desert. This area receives about 14.7 inches of rain a year, most of that falling in the summer months, the monsoon season. Distant mountain ranges block moisture from the Pacific Ocean, as warm moist air off the ocean rises and cools causing rainfall on the ocean-side of the mountains. About 90% of the annual rainfall occurs between July and October. The summer monsoon or rainy season in characterized by thunderstorms that build in the afternoon (Serrat-Capdevila et al. 2007). However winter storms deliver rain and snow, which can be significant as well. Evapotranspiration is lower in the winter, and the rainfall is of greater duration but lower intensity – and may be combined with snowfall at higher elevations. Consequently, more moisture soaks into soils and becomes a very important source of groundwater recharge in the mountains and along the mountain fronts (valley margins). Although winter rains are less than half the annual precipitation they are responsible for a major portion of the annual recharge (Poole and Coes 1999, Eastoe et al 2004, Serrat-Capdevila et al. 2007). The types of storms associated with different seasons and weather patterns also affect the types of fluvial erosion and deposition that take place (Price et al. 2005). Perennially-flowing reaches depend on groundwater discharge, which may occur as seepage or spring discharge from the surrounding alluvial aquifer or from an underlying basin-fill aquifer, water from which is forced to the surface by bedrock constrictions.

Daily stream flows for the San Pedro River typically have high flows during summer monsoons, with occasional years where winter/spring flows exceeded monsoon flows, as illustrated in Stromberg et al. (2009).

Streams of this ecosystem include both "gaining" and "losing" reaches. Gaining reaches are where groundwater flows into the stream and losing reaches occur where surface water leaks into underlying aquifers, resulting in a reduced or complete cessation of flow. Alternating gaining and losing reaches can result in a naturally patchy distribution of aquatic, hyporheic, and riparian habitat. Evaporation and riparian transpiration also consume water seasonally, contributing to losses of flow along individual stream reaches during the growing season, except during runoff flow pulses. Riparian water table dynamics follow suit: the water table rises during high-flow events and falls between such events, unless the water table is controlled primarily by an upward leakage of groundwater from deeper aquifers, forced to the surface by bedrock sills (e.g., Webb and Leake 2006).

Average water temperatures and concentrations of particulate organic matter are higher during runoff pulses, as are concentrations of suspended and re-suspended sediment. In contrast, average water temperatures and concentrations of particulate organic matter are lower during baseflow, as are concentrations of suspended and re-suspended sediment.

Fire can also play an important role in shaping the vegetation along streams. Very hot fires can kill cottonwood trees and in drier reaches may stimulate growth of already present salt cedar (*Tamarix*)(Stromberg et al. 2009). Along more wetted and regularly flooded reaches, fires cause less mortality, probably due to the removal of woody debris by floods, the more open stature of the trees, and higher moisture of vegetation. Fire in adjacent sacaton grasslands allowed grasses to maintain dominance and reduced woody growth such as mesquite (Wright 2002, Stromberg et al. 2009).

C-7.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque / Stream ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-7.5.1 List of Primary Change Agents

Occurrences of this ecosystem – both their riparian areas and aquatic communities – are directly affected by concentrated grazing, cutting of woody vegetation, land development, river channelization including channel dredging and bank armoring, diversion of flows, withdrawals of groundwater, wildfire suppression, exotic terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized), roadways and railways that cut through/along riparian corridors, mining, point-source and diffuse (runoff) pollution, and fragmentation by dams. Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover and through water diversions and withdrawals; or that result in point and non-point-source pollution, including from abandoned and active mines and possibly from atmospheric deposition.

C-7.5.2 Altered Dynamics

Table C-28 identifies the most likely impacts associated with each of the stressors identified in Section C-7.5.1. Change agents, and the specific stressors they generate, which can cause alteration to the Key Ecological Attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the Conservation Element, such as new rural or urban development. Other stressors such as roads and other infrastructure corridors (e.g. railroads, power lines, solar arrays, oil pumping platforms and the like) cause fragmentation in the distribution or connectivity of the Conservation Element (Debinski and Holt 2001). Irrigated agriculture, in addition to completely removing portions of a Conservation Element, can also cause downstream alteration to a riparian/stream ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects can have a double effect on aquatic CEs, as they can change the amount and timing of flow, and also can fragment the network of flow (Poff et al. 2010). Aquatic invasive species can have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in Key Ecological Attributes of Biotic Condition for riparian/stream ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful, causing alteration to functional diversity and food web structure (Calamusso et al. 2005). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure. Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling or cause changes in vegetation on stream banks that affect bank and channel stability; and changes in beaver populations can change hydrology and nutrient cycling. Figure C-24 and Figure C-25 capture these interactions and the use of indicators to track them.

Table C-28. Stressors and their likely impacts on the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review, of which there are many for each stressor).

Stressor	Impacts
Land Use	
Concentrated grazing	Removal of native vegetation, changes to native composition and structure, possibly favoring invasion of non-native vegetation (Patten 1998), loss of regenerating native cottonwoods and willows (Robinett 2005b) thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008); erosion of stream banks and channel; stream pollution (sediment, manure) (Robinett 2005b) which can be detrimental to fish habitats (Calamusso 2005).
Unregulated recreation	Elimination and fragmentation of riparian habitat; increased soil erosion; point and non-point source pollution, cutting of woody vegetation, (Debinski and Holt 2000).
Cutting of woody vegetation	Removal of native vegetation, possibly favoring invasion of non-native vegetation (Patten 1998, Stromberg et al. 2009), thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008) which can impact the amount of woody debris important for fish habitat (Calamusso 2005).
Development	
Roadways/railways	Elimination and fragmentation of riparian habitat; altered longitudinal surface flow paths in alluvial aquifer; non-point source pollution (Comer and Hak 2009).
Mining within riparian zone	Elimination and fragmentation of riparian habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; point source pollution (Mol and Ouboter 2004, Berkman and Rabeni 1987).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Webb and Leake 2006, Poff et al. 2010, Anning et al. 2009).
Land development	Elimination and fragmentation of riparian habitat; reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Fragmentation by dams	Fragmentation of riparian habitat and aquatic connectivity very important to fish habitat (Calamusso 2005)

Stressor	Impacts
Hydrologic Alterations	
River channelization	Elimination of natural geomorphic dynamics; elimination of bank and over-bank recharge to alluvial aquifer during runoff pulses; elimination of groundwater discharge along armored reaches; channel entrenchment resulting in lowered groundwater table (Noonan 2013) which degrades fish habitat (Calamusso 2005).
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, disconnect with the floodplain which can increase sediment transport and change the aquatic habitat (Calamusso 2005, Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010), causing loss to flora an faunal ecology (Patten 1998, Stromberg et al. 2007, Faber-Langendoen et al. 2008).
Point-source pollution along riparian zone	Direct alteration of surface water and potentially also groundwater quality which can lead to poor water quality detrimental to fish habitats.
Point-source pollution, watershed	Alteration of water quality in flows arriving from upstream and tributaries which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Non-point-source pollution	Alteration of water quality in flows arriving from upstream and tributaries as well as in surface runoff along/within the riparian zone itself Abell et al 2000) which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table (Stromberg et al 1996, Calamusso 2005, Poff et al. 2010). Changes in flow can cause increased channel incision and down cutting of the stream bed (Noonan 2013), and cause severe habitat changes such as loss of mature trees, bank erosion and widened channel and wetland grassed and forbs are replaced by annuals (Robinett 2005b, Falke et al. 2011).
Changes to natural Wildfire regime	Change in vegetation succession dynamics, such as the encroachment and increase density of native and non-native woody species, such as tamarisk , and hot fires that change soil characteristics (Stromberg et al. 2009, Stromberg and Rychener 2010, U.S. Fish and Wildlife Service 2002) ().
Invasive Species	
Exotic terrestrial plants and animals	Replacement of native vegetation, altering riparian habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality;, alteration of fire risk; alteration of soil and channel stability either through an increase (such as tamarisk thickets) or decrease (annuals replacing perennial graminoid species); alteration of ground-litter chemistry; alteration of evapotranspiration rates and timing (Stromberg 1998, Robinett 2005b).

Stressor	Impacts
Exotic aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Rinne 1996, Calamusso 2005, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

C-7.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-7.6.1 Key Ecological Attributes

Table C-29 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-29. Key Ecological Attributes (KEA) of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem. [additional citations to be added]

KEA Class: Name	Definition	Rationale	Stressors
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the riparian/stream ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Surrounding watershed cover also shapes the connectivity between the riparian/stream corridor and the surrounding landscape for fauna that move between the two settings; and the longitudinal connectivity of the buffer zone alongside the corridor within which additional wildlife movement takes place. (Comer and Hak 2009)	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Development and excessive grazing also can introduce pollutants and cause fragmentation (reduces connectivity) between the riparian/stream corridor and the surrounding landscape and along the buffer zone surrounding the corridor. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Vegetation Corridor Extent**	The longitudinal extent of uninterrupted (unfragmented) native vegetation patches along the riparian corridor.	Unfragmented riparian corridors support individual animal movement, gene flow, and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend. More extensive and highly connected riparian corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance or incursions by non-native species (Faber-Langendoen et al. 2012b). Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic will not be used as a measure of health.	Stressors to vegetation corridor extent include development on/in the riparian corridor itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in vegetation corridor extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
***Size/Extent:* Aquatic Corridor Extent**	The longitudinal extent of the stream channel network, uninterrupted by barriers or reaches without even naturally seasonal or intermittent flow.	Unfragmented aquatic corridors support up- and downstream movement and gene flow for aquatic animal species, natural downstream transport of larvae and seeds, and natural downstream transport of sediment and both dissolved and suspended nutrient matter -- all processes crucial to sustaining the aquatic food web, aquatic and riparian species populations, and succession and recovery from disturbances. More extensive and highly connected aquatic corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance. Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic will not be used as a measure of health.	Stressors affecting aquatic corridor extent include dams and diversions, riparian corridor development (see Vegetation Corridor Extent), surface- and groundwater use (see Hydrologic Regime), channelization (see Geomorphology), and concentrated contamination such as from mine waste (see Water Chemistry). Climate change also has the potential to cause additional change in aquatic corridor extent, through its impacts on hydrology (see Hydrologic Regime).
***Biotic Condition:* Riparian Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the riparian corridor including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the riparian faunal assemblage are important aspects of the ecological integrity of a riparian ecosystem. Numerous native species of birds, mammals, reptiles and amphibians, and invertebrates use riparian habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to riparian vegetation composition, riparian corridor connectivity, soil moisture, and the availability of surface water. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic and functional composition of the riparian faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Riparian & Aquatic Flora**	The taxonomic composition of the native floral assemblage of the riparian corridor including woody and non-woody vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the riparian & aquatic floral assemblage is an important aspect of the ecological integrity of a riparian/aquatic ecosystem. Numerous native species of woody and non-woody plants occur preferentially or exclusively in riparian habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to riparian corridor hydrology (e.g., water table and flood dynamics), aquatic and riparian corridor connectivity (affecting availability of seed for recolonization following disturbance), and altered water quality. Alterations in the taxonomic composition of the riparian floral assemblage beyond its natural range of variation therefore strongly indicates the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic composition of the riparian native floral assemblage experiences include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the stream, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage are important aspects of the ecological integrity of a stream ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to stream hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
***Abiotic Condition:* Hydrologic Regime**	The pattern of surface flow in the stream channel and surface-groundwater interaction along the riparian corridor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; and the magnitude of seasonal and annual water table mean elevation.	The surface flow regime determines which aquatic species can persist in a stream system through their requirements for or tolerances of different flow conditions at different times of the year; shapes sediment transport and geomorphology and therefore aquatic habitat distributions and quality; and determines the pattern of flood disturbance. In turn, interactions between the surface flow regime and underlying aquifer conditions shape the pattern of baseflow in the former and the pattern of water table variation along the riparian corridor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and riparian habitat and biological diversity (e.g., Poff et al. 1997; Collins et al. 2006; Poff et al. 2007).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; riparian corridor development; and alterations to the riparian floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the riparian zone and across the surrounding watershed. Climate change may also cause changes in human water use.
***Abiotic Condition:* Geomorphology**	The geomorphology of the stream channel, banks, and floodplain, including channel steepness, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Channel and floodplain geomorphology, shaped by watershed runoff (sediment and water) and surface flows in the stream, create the habitat template for both riparian and stream flora and fauna. Altered channel substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both stream-floodplain and surface-groundwater interactions along riparian corridors.	Stressors affecting the geomorphology of the stream channel, banks, and floodplain include the cumulative effects of alterations to watershed cover, riparian and aquatic corridor connectivity, riparian flora, and hydrology; the effects of bank and channel trampling from excessive use by livestock; and the effects of direct channel and floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in stream channel morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the water moving into the riparian corridor water table and along the stream channel, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through riparian and stream habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and stream water chemistries. Stream fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants.	Stressors affecting water quality include the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
Abiotic Condition: **Fire**	The pattern of fire occurrence (fire regime) within the riparian corridor, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in riparian vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and riparian corridor vegetation due to other factors.

C-7.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in Table C-29 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-30. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-30. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table C-30. Relationship of Key Ecological Attributes (KEA) for the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X		X	
Vegetation Corridor Extent		X		X
Aquatic Corridor Extent		X		X
Biotic Condition: Riparian Fauna		X		X
Biotic Condition: Riparian and Aquatic Flora		X		X
Biotic Condition: Aquatic Fauna		X		X
Abiotic Condition: Hydrologic Regime	X	X		X
Abiotic Condition: Geomorphology	X	X		X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X		X

C-7.8 Conceptual Model Diagrams

Figure C-24. Conceptual model diagram for North American Warm Desert Riparian Woodland and Aquatic Stream Ecosystem describing the structural components and functional relationships that characterize this system. Ovals represent Key Ecological Attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

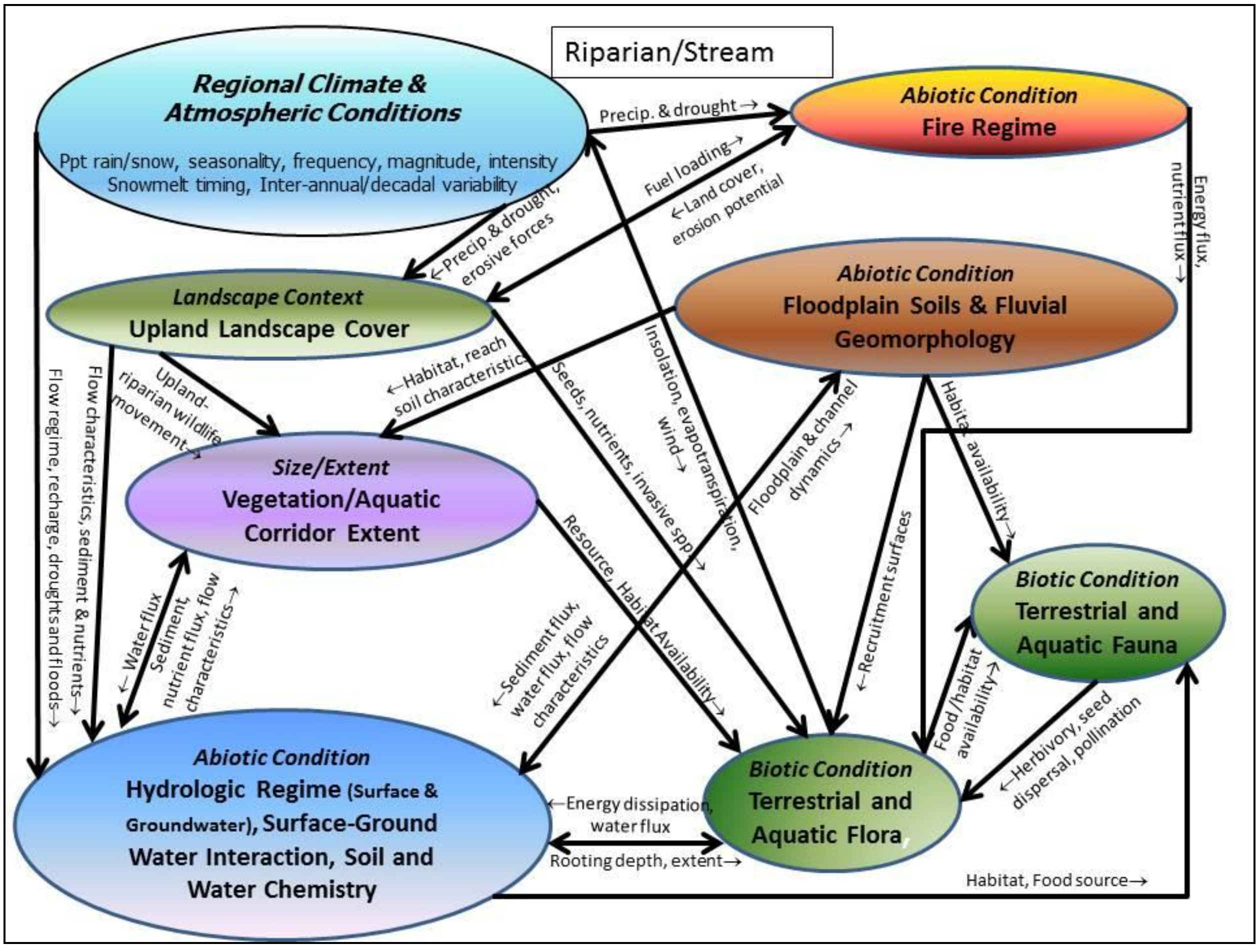
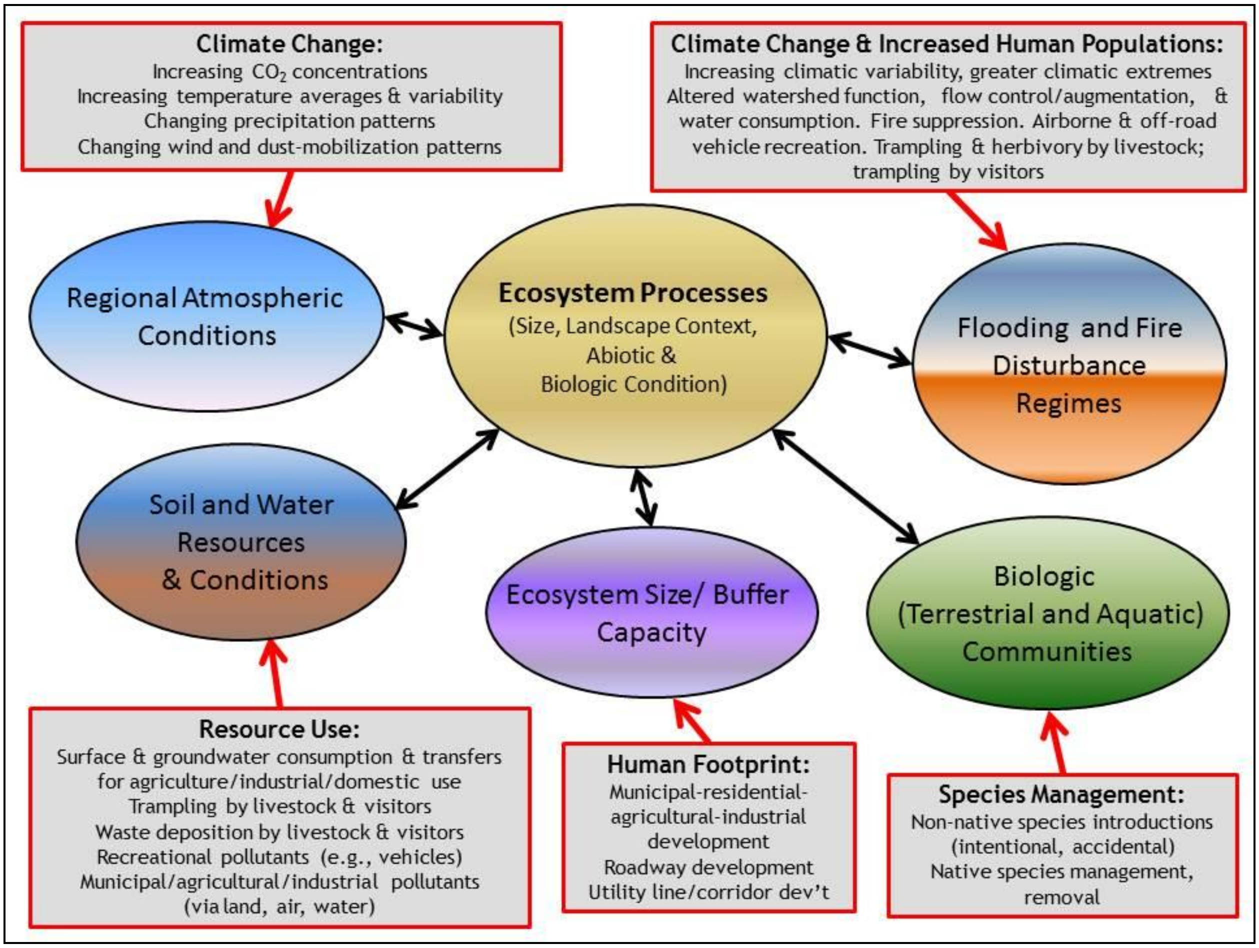


Figure C-25. Some of the major stressors affecting riparian ecosystem's key ecological attributes.



C-7.9 References for the CE

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Desert Marshes and Cienegas

C-8 North American Warm Desert Ciénega Ecosystem

C-8.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) Tobosa/Sacaton swale (intermittently flooded)

- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)
- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)Summary

This spring-fed marsh ecosystem (Figure C-26) occurs at mid to low elevations (<2000 m, 6562 feet) across the warm deserts of western North America. "Ciénegas" are freshwater spring-fed wetlands, characterized by non-fluctuating shallow surface water (PAG 2001, Stromberg et al. 2009); the term ciénega was applied to riparian marshlands by Spanish explorers. These wetlands are found embedded in landscapes dominated by semi-desert grasslands and Madrean evergreen woodlands. Ciénegas are characterized by permanently saturated, highly organic, reducing soils and a relatively simple flora dominated by low stature herbaceous hydrophytes (water loving plants), with only occasional patches of trees (Hendrickson and Minckley 1984, Stromberg et al. 2009, Stevens et al. 2012). Historically, ciénegas were much more abundant within the MAR, and were persistent part of the landscape with infrequent cycles of incision, such that they are considered a type of climax vegetation (Hendrickson and Minckley 1984). After 1870 and the influx of European setters, their livestock and coincidental drought cycle, severe changes occurred in the hydrology and plant cover with ciénega wetlands, causing arroyo formation (Figure C-26) and the loss of many ciénegas (Hendrickson and Minckley 1984, Noonan 2013). Today ciénegas are very rare (Stefferud et al. 2009) and are generally isolated from direct stream flow (that is outside of active channels, but still adjacent to them), although can be hydrologically connected through the interaction of surface flow and groundwater sources such as shallow aquifers, as shown to be the source of water for the Bingham Ciénega (PAG 2001).

Figure C-26. Photos of North American Warm Desert Ciénegas. Left—St. David Ciénega, San Pedro River (Stevens et al. 2012). Right—Arroyo where a ciénega once stood, created by severe down cutting flooding caused by drought and loss of vegetative cover (Hendrickson and Minckley 1984, Noonan 2013).

In the MAR ciénegas occurred historically at low and mid-elevations stream channels with perennial springs. Ciénegas are perpetuated by permanent, minimally fluctuating sources of water, and when they were abundant experienced low probability of scouring from floods (Hendrickson and Minckley 1984). Today they occur on small, low-energy rivers and have low frequency of scouring floods and typically sustained by groundwater inflow (Hendrickson and Minckley 1984, Stromberg et al. 2009). The hydrology is controlled by permanently saturated hydrosols, with reducing conditions limiting the type of plant life that may grow there. Soils can have many meters of organic deposition(Stromberg et al.

1996). Plant life is limited to low shallow-rooted semi-aquatic sedges such as spike-rush (*Eleocharis* spp.), rushes *(Juncus* spp.), sedges (*Carex* spp.) a few grasses, and more rarely, cattails (*Typha spp*.) (Stromberg et al. 2009, Stevens et al. 2012). Forbs include whorled marshpennywort (*Hydrocotyle verticillata*), and creeping primrose-willow (*Ludwigia natans*), which can be rooted in patches of gravel below organic root zone in pool bottoms (Stromberg et al. 2009, Stevens et al. 2012). Few trees and shrubs may be present such Godding's willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii*), velet ash (*Fraxinus velutina*)and common button bush (*Cephalanthus occidentalis*) (Stromberg et al. 2009, Stevens et al. 2012).

The type and pattern of vegetation depends on depth of water. In shallow pool margins, emergent plants include species of *Eleocharis, Carex, and Juncus*. Taller marsh vegetation can be found in adjacent deeper waters, such as cattails (*Typha*), bulrush (*Schoenoplectus*) and reed canary grass (*Phalaris*). Ciénegas may also include areas of relatively deep water with floating-leaved plants (*Lemna, Potamogeton*, *Polygonum* and *Brasenia*) and submergent and floating plants (*Myriophyllum, Ceratophyllum*, and *Elodea*).The outer margins of a ciénega may have saline soils due to capillary action and evaporation, where salt- tolerant species such as *Distichlis spicata* and *Sporobolus airoides* may be abundant (Stevens et al. 2012). Ciénegas tend to have deep organic soils and are very productive ecosystems.

Faults along mountian fronts provide for springs and deep alluvial soil serves as an aquifer for groundwater storage, as well as shallow aquifers and the interaction between surface water and groundwater, two important sources of water for ciénegas (PAG 2001).

C-8.2 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Animals listed are from Stromberg et al. 2009.

Reptiles and Amphibians: Sonoran Mud Turtle, Slevin's Bunchgrass Lizard, Desert Grassland Box Turtle, Madrean Alligator Lizard, Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*), Ring-necked Snake, Mexican gartersnake, Woodhouse's Toad, Arizona Toad (*Anaxyrus microscaphus*), Narrow-headed Gartersnake, Lowland leopard Frog.

Mollusks: Page springsnail (*Pyrgulopsis morrisoni*), *Tryonia* spp. and *Fontelicella* spp.

Invertebrates: Sunrise skipper (*Asopaeoides prittwitzi*)

Birds: Black Phoebe, Common yellow throat, Killdeer

Fish: Desert pupfish (*Cyprinodon macularius)*, Gilia and Sonoran topminnows (*Poeciliopsis occidentalis*, subspp *occidentalis* and *sonoriensis*), Gila Chub (*, Gila intermdia),* and Yaqui Chub *(Gila purpurea*)

Mammals: white-footed mouse, beaver.

Plants: Canelo Hills ladies tresses (*Spiranthes delitescens*)

C-8.3 Natural Dynamics

Ciénegas described here are isolated spring-fed wetlands found at the outer edge of floodplains and valley floors. Therefore they have relatively stable surface hydrologic dynamics. As such they are entirely dependent on groundwater flow to their source spring, and are very sensitive to changes in groundwater levels (Hendrickson and Minckley 1984, Stromberg et al. 1996, Stromberg et al. 1997, Bagstad et al. 2005, Stromberg et al. 2009, Noonan 2013). Overland surface flow from intense monsoon rains in the summer may deliver sediments into the ciénega, depending on the amount of vegetation and exposed soils on hill slopes above. Winter storms are less intense and are more likely to result in soil moisture absorption, ground water recharge, and less surface runoff. Groundwater level stability is key to maintaining ciénegas (Hendrickson and Minckley 1984, Stromberg et al. 1996, Stromberg et al. 1997, Bagstad et al. 2005, Stromberg et al. 2009, Noonan 2013). Springs and associated marsh plant communities that occur within an active steam channel are subject to the dynamics of high and low channel flows, and are treated as part of the North American Warm Desert Riparian/Stream and North American Warm Desert Lower Montane Riparian/Stream Conservation Elements for the MAR assessment.

In the past, ciénegas were more extensive and were a result low gradients , fine sediments, and dense vegetation that could slow channel surface water flows and by being surrounded by low-relief rolling grasslands or alluvial plains that absorbed rains, slowing runoff by dense upland grassland vegetation, low slope gradients and deep soils (Hendrickson and Minckley 1984). When cattle and drought arrived (around 1870), the combination changed the surrounding landscape and decreased the amount of vegetation, exposing soils, resulting in much more erosive runoff during monsoons (Noonan 2013). The erosive power of runoff and subsequent channel flows caused massive downcutting of channel floors, dropping the groundwater table, changing the low gradient, high water table mid- elevation stream channel into dry, deep arroyos,, with larger more coarse sediments, completely eliminating or significantly reducing the ciénega ecosystem footprint (Hendrickson and Minckley 1984, Stromberg et al. 2009, Noonan 2013).

It is possible and has been observed that with a period of flow stability wetland plants will invade saturated streambeds in arroyos and begin organic deposition (Noonan 2013). Vegetation development will continue to build under continued stable flow regimes. These newly formed wetlands may be washed away by subsequent floods, but with enough time, may develop enough to withstand some flooding (Hendrickson and Minckley 1984, Stromberg et al. 1997, Noonan 2013). As organic materials accumulate, water levels rise and soil moisture storage increases. Once matured, ciénegas can act as climax communities that are self-protecting and water-storage systems, that is once they are large enough they are better able at buffering once destructive high flows (Hendrickson and Minckley 1984). Flows downstream from ciénegas are less variable and of greater permanence than flows in streams without them. The large storage capacity and slow release of water can dampen and attenuate flood peaks. This is conducive to the establishment and growth of ciénegas downstream, and the increase in vegetation can cause deposition of additional clays and silts, allowing for upstream development (Hendrickson and Minckley 1984). Increased water storage and sediment trapping means flows downstream have less sediment and increased erosive power, causing downcutting and deep pool formation. Thus it may be quite possible for restoration of ciénegas in mid-elevation arroyos (Stromberg et al. 1997, Stromberg 2001, Stromberg et al. 2007, Noonan 2013).

Therefore the perpetuation of ciénega habitat requires maintenance of permanent groundwater and a balance between sedimentation and flushing flows (Hendrickson and Minckley 1984).

C-8.4 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Ciénega ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-8.4.1 List of Primary Change Agents

Occurrences of this ecosystem are directly affected by concentrated grazing on site, land development, withdrawals of groundwater, wildfire suppression, exotic terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized). Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover.

C-8.4.2 Altered Dynamics

Table C-31 identifies the most likely impacts associated with each of the stressors identified. Change agents, and the specific stressors they generate, cause alteration to the Key Ecological Attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the Conservation Element, such as active downcutting and lowering of groundwater, or new rural or urban development. Irrigated agriculture, in addition to complete removing portions of a Conservation Element, can also cause downstream alteration to a ciénega ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Aquatic invasive species can have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in Key Ecological Attributes of Biotic Condition for ciénega ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented (Calamusso et al. 2005) As native species become stressed more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure (Stromberg 2001). Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling (Tabacchi et al. 1998) or cause changes in vegetation on stream banks that affect bank and channel stability (Micheli and Kirchner 2002); and changes in beaver populations can change hydrology (Naiman et al. 1988, Rosell et al. 2005, Lewis et al. 2009) and nutrient cycling (Lewis et al. 2009). Figure C-27 and Figure C-28 capture these interactions, and the use of indicators to track them.

Table C-31. Stressors and their likely impacts on the North American Warm Desert Ciénega ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review, of which there are many for each stressor).

Stressor	Impacts
Land Use	
Continuous Heavy Livestock grazing	Removal of native vegetation, possibly favoring invasion of non-native vegetation; disruption of spring structure, associated pools and outflow channels; (Stevens and Meretsky 2008) increase water pollution (sediment, manure), which is detrimental to fish habitat (Calamusso 2005,).
Recreation	Elimination and disturbance of ciénega habitat; increased soil erosion; soil compaction, non-point source pollution, reduction spring-upland trophic linkage, potential fire starts (Debinski and Holt 2000, Stevens and Meretsky 2008).
Development	

Stressor	Impacts
Roadways/railways	Elimination and fragmentation of spring habitat; altered surface water flow paths; non-point source pollution (Comer and Hak 2009).
Mining	Elimination of spring habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; source of pollution and sedimentation (Mol and Ouboter 2004, Berkman and Rabeni 1987).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately surrounding the ciénega buffer area; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Webb and Leake 2006, Poff et al. 2010, Anning et al. 2009).
Land development	Reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Hydrologic Alterations	
Spring Development /Alteration	Direct local elimination of natural spring geomorphic structure, reduction in soil moisture absorption, physical disruption of pool/bank ratio. (Stevens and Meretsky 2008) Post-orifice diversion is also common, particularly for livestock watering and development of ponds. Spring flows are commonly captured into open troughs or into covered tanks and then piped to troughs or ponds. These alterations often eliminate spring channel and ciénega (wet meadow) functions (Stevens and Meretsky 2008).
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, which can come from activities far removed from spring location (Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010).
Point-source pollution, watershed	Alteration of water quality of groundwater sources (Anning et al. 2009). Groundwater and surface water pollution strongly alters springs ecosystem integrity and is a common phenomenon in agricultural and urban areas. Agricultural groundwater pollution may shift ecosystem nutrient dynamics to entirely novel trajectories creating conditions to which few native species may be able to adapt (Stevens and Meretsky 2008). Local contamination may also affect springs microhabitats by polluting surface waters. Such impacts are abundant at springs on the southern Colorado Plateau where springs sources are often fenced and concentrate ungulate use (Stevens and Meretsky 2008).
Non-point-source pollution	Alteration of water quality in surface storm runoff into the ciénega itself, which can come from agricultural and urban areas within the watershed, which can be detrimental to fish habitat (Abell et al 2000, Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table, adds stress to fish habitat (Stromberg et al 1996, Calamusso 2005, Poff et al. 2010).

Stressor	Impacts
Wildfire suppression	Change in vegetation succession dynamics, possibly also favoring invasion of non-native vegetation (Unnash et al. 2008). Also, changes in land use by fire suppression can change the role of plant water use in a watershed and subsequently recharge to the aquifer (Stevens and Meretsky 2008)
Invasive Species	
Exotic terrestrial plants and animals	Replacement of native vegetation, altering ciénega habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality; alteration of fire risk; alteration of soil and ground-litter chemistry; alteration of evapotranspiration rates and timing (Stromberg 1998).
Exotic aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Rinne 1996, Calamusso 2005, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of soil moisture, runoff (surface flows) and recharge (groundwater quantity) at both the watershed scale and immediately within ciénega and buffer. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

C-8.5 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-8.5.1 Key Ecological Attributes

Table C-32 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-32. Key Ecological Attributes (KEAs) of North American Warm Desert Ciénega and Pond ecosystem.

KEA Class: Name	Definition	Rationale	Stressors
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the ciénega ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion, and transport of sediment, dissolved and suspended nutrients to the ciénega location from the watershed as a whole and from its immediate buffer zone. Surrounding watershed cover also influences groundwater recharge rates (Comer and Hak 2009, Stevens and Meretsky 2008).	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the ciénega location from the watershed as a whole and from its immediate buffer zone. Development and excessive grazing also can introduce pollutants and reduces connectivity between the ciénega and the surrounding landscape and along the buffer zone surrounding the ciénega. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Relative Size**	The size of the ciénega relative to historic extent.	Ciénegas can be naturally very small occurrences, so absolute size alone will not indicate the health of a spring system. However the historic extent of ciénegas was much more extensive than today. Larger more complex ciénega has higher habitat heterogeneity and greater buffer capacity. Understanding the degree of reduction in the footprint of ciénegas is critical to understand the loss of wetland habitat throughout the watershed. Knowledge of historic extent can also be very useful for understanding restoration potential (Stevens and Meretsky 2008, Hendrickson and Minckley 1984).	Stressors to vegetation corridor extent include development on top of the ciénega itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of ground water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in ciénega extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Aquatic Flora**	The taxonomic composition of the native floral assemblage of the ciénega emergent vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the ciénega wetland floral assemblage is an important aspect of the ecological integrity. Numerous native species of woody and non-woody plants occur preferentially or exclusively in ciénega habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to ciénega hydrology (e.g., water table and spring flow dynamics), and altered water quality. Alterations in the taxonomic composition of the ciénega floral assemblage beyond its natural range of variation therefore strongly indicate the types and severities of stresses imposed on the ciénega ecosystem.	Stressors to the taxonomic composition of the ciénega native floral assemblage experiences include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the ciénega ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ciénega, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage is an important aspect of the ecological integrity of a ciénega ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to ciénega hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ciénega aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the ciénega ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of ground water flow to the surface (source springs) and the surface-groundwater interaction along the valley floor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; the magnitude of seasonal and annual water table mean elevation, and aquifer responsiveness.	The ground water outflow regime determines which aquatic species can persist in a ciénega system through their requirements for or tolerances of different flow rates at different times of the year; shapes downstream sediment transport and geomorphology and therefore aquatic habitat distributions and quality. Interactions between the surface flow regime and underlying aquifer conditions also shape the pattern of baseflow and the pattern of water table variation along the valley floor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and marsh habitat and biological diversity (e.g., Poff et al. 1997; Collins et al. 2006; Poff et al. 2007, Stevens and Meretsky 2008).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; ciénega development; and alterations to the ciénega floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the ciénega and across the surrounding watershed. Climate change may also cause changes in human water use.
Abiotic Condition: **Geomorphology**	The geology and geomorphology of the spring source and its immediate outflow pool / channel, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Spring geology and geomorphology create the habitat template for aquatic and wetland flora and fauna. Altered spring substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both spring-wetland and surface-groundwater interactions within ciénegas.	Stressors affecting the geomorphology of the ciénega soils, pool depth, and surrounding buffer include the cumulative effects of alterations to watershed cover, flora, and hydrology; the effects of ciénega trampling from excessive use by livestock; and the effects of direct floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in ciénega morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the water flowing into ciénegas including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through ciénega habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and water chemistries. Ciénega fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants.	Stressors affecting water quality include the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
Abiotic Condition: **Fire**	The pattern of fire occurrence (fire regime) in the surrounding landscape, as well as in ciénegas, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in wetland vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients (Luce et al. 2012). More importantly for ciénegas, the surrounding landscape natural fire regime is an important regulator of fuel loads and subsequent intensity of fires which affect the likelihood of sediment input.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and ciénega vegetation due to other factors. Fires can mimic disturbance (Conway et al. 2010) to the benefit of disturbance adapted species. However fire in cienegas would remove vegetation and could reduce ability to slow surface waters in post-fire high flows. Another outcome of fire may be the removal of encroaching woody species, and can stimulate regrowth of native species, depending on the context (Stromberg and Rychener 2010).

C-8.6 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes listed in Table C-32 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-33. Here we try and relate those 4 fundamentals to the KEAs in this Conceptual Model. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-33. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table C-33. Relationship of Key Ecological Attributes (KEA) for the North American Warm Desert Ciénega ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X	X	X	
Size/ Extent Relative Size	X	X	X	X
Biotic Condition: Aquatic Fauna		X		X
Biotic Condition: Aquatic Flora		X		X
Abiotic Condition: Hydrologic Regime	X	X		X
Abiotic Condition: Geomorphology	X	X		X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X		X

C-8.7 Conceptual Model Diagrams

Figure C-27. Conceptual model diagram for North American Warm Desert Ciénega/Marsh/Pond Aquatic Ecosystem describing the structural components and functional relationships that characterize this system. Ovals represent Key Ecological Attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

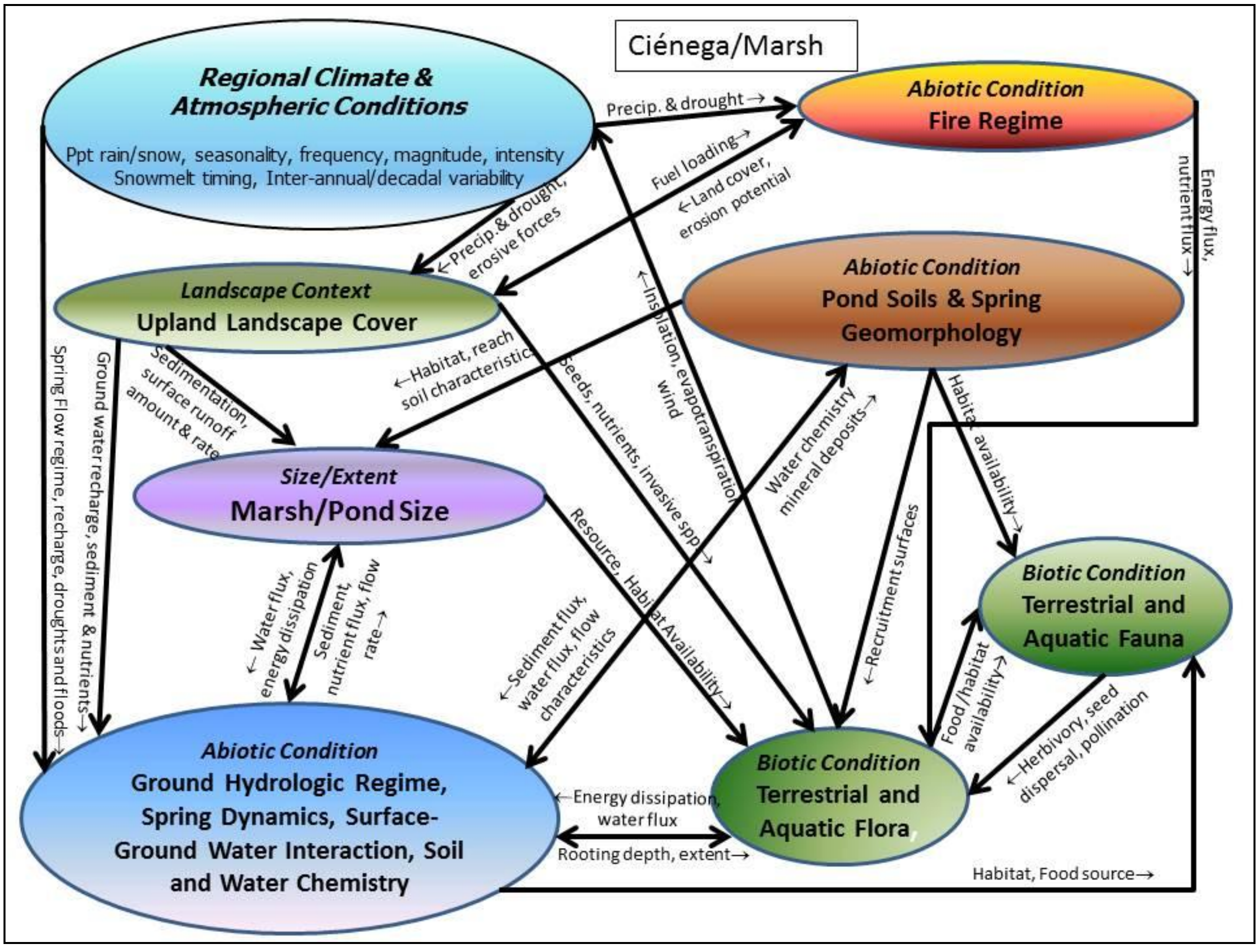
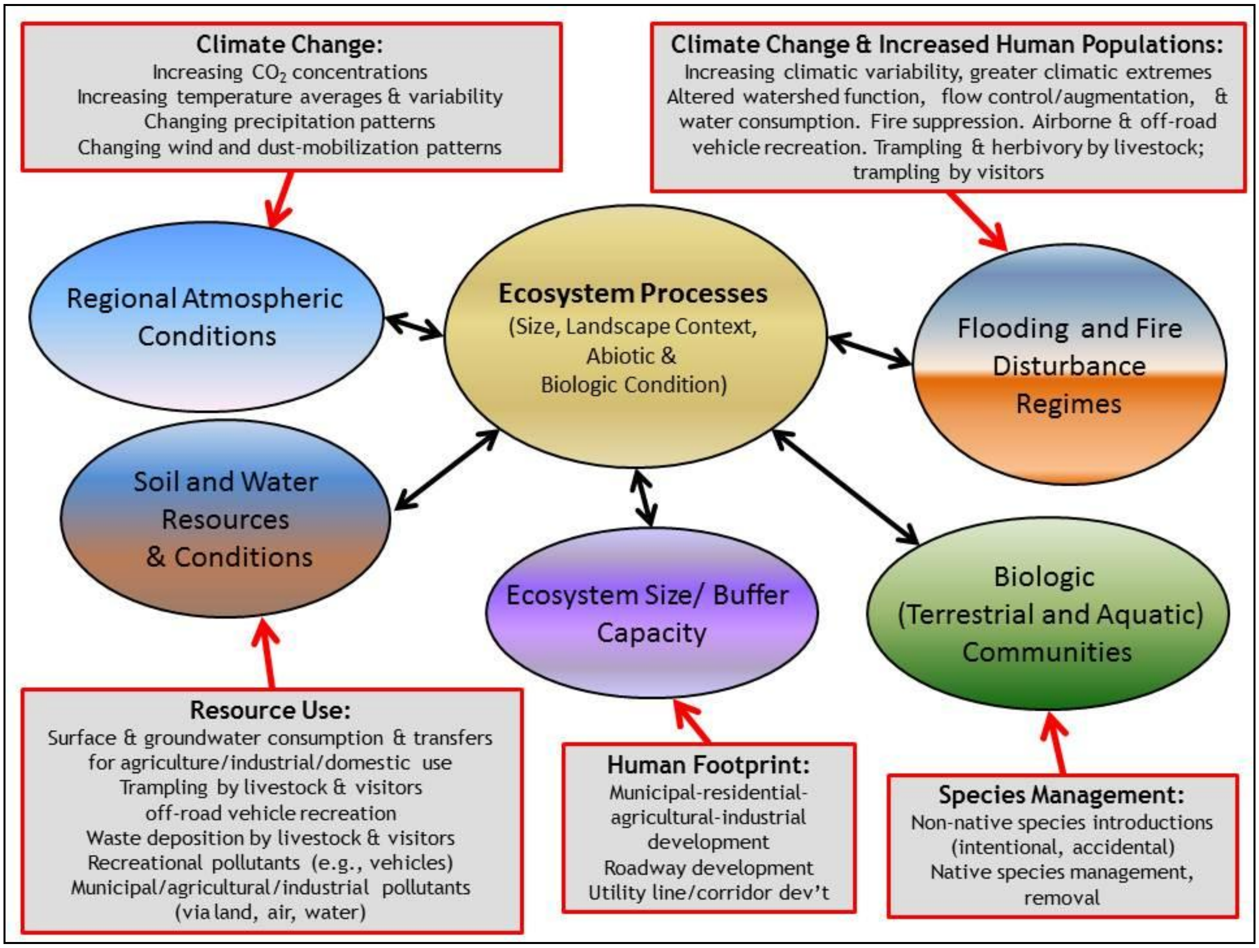


Figure C-28. Some of the greatest stressors affecting North American Warm Desert Ciénega/Marsh/Pond Ecosystem Key Ecological Attributes.



C-8.8 References for the CE

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Montane River and Riparian

C-9 North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream

C-9.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)
- North American Warm Desert Riparian Mesquite Bosque (CES302.752)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)

C-9.2 Summary

This ecological system occurs in foothill and mountain canyons and valleys of the warm desert regions of the southwestern U.S. and adjacent Mexico. It consists of riparian corridors and along perennial and seasonally intermittent streams or rivers (Figure C-29) at lower montane elevations, generally between 4,000 – 7,000 ft. (1200-2150 m)[2] with variation due to hydrogeologic setting. Rivers include upper portions of the Gila, Santa Cruz, Salt, San Pedro, and their tributaries. The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Populus angustifolia, Populus tremuloides, Acer negundo, Populus deltoides ssp. wislizeni, Populus fremontii, Platanus wrightii, Juglans major, Cupressus arizonica, Fraxinus velutina*, *Quercus gambelii* and *Sapindus saponaria*. Shrub dominants include *Salix exigua, Prunus* spp., *Alnus oblongifolia*, and *Baccharis salicifolia*. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction. The Coronado National Forest has identified the vegetated portions of this system as the "Mixed Broadleaf Deciduous Riparian Forest" and the "Montane Willow Riparian Forest". National Resource Conservation Service recognizes this ecosystem as the Sandy Bottom (PLWR2, POFR2) F041XA113AZ Ecological Site Description (Robinett 2005b).

The aquatic fauna and flora in this ecosystem type vary depending on whether flow is perennial or intermittent; the frequency, intensity, seasonal timing, and duration of high-flow pulses, low-flows, and dry conditions; the relative contributions to stream flow from runoff from rainfall and snowmelt versus from groundwater discharge, including discharge from discrete springs; water temperature and chemistry; channel substrate and form, including the distribution of shaded pools; the extent of the hyporheic zone; and drainage network connectivity.

As with all warm desert streams and rivers, this ecosystem supports a unique range of aquatic species adapted to the overall scarcity and irregular availability of water over space and time, and the frequent isolation of perennial reaches by dry conditions across the rest of the drainage network. These factors result in a high degree of endemism among the aquatic biota, including species adapted to using pools or the hyporheic zone as their main habitat or as refuge during periods with low, intermittent, or no flow. This ecosystem occurs at higher elevations than the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream ecosystem, and consequently has typically steeper channel gradients resulting in generally cooler water temperatures, higher flow velocities, and a higher proportion of habitats with coarse (versus fine) substrate and bank sediments. This ecosystem also often occurs in canyons, where surrounding bedrock confines the channel both vertically and

[2] tentative proposed elevation band, specific to the MAR

horizontally, and where debris from the surrounding slopes such as snags and large boulders contribute to habitat complexity.

These factors select for a unique spectrum of aquatic species in this ecosystem. For example, benthic macroinvertebrate assemblages generally consist of highly tolerant, short-lived, fast-reproducing individuals with broad ecological tolerances, with an emphasis on collectors/gatherers and grazers. Vertebrate and invertebrate species able to use the hyporheic zone as their main habitat or as a refuge during periods without flow or during extreme flow pulses occur in this system type (e.g., Del Rosario and Resh 2000, Levick et al. 2008. Disturbances caused by intermittent flows may actually facilitate high food quality and consequently high levels of insect production (Fisher and Gray 1983, Jackson and Fisher 1986, Grimm and Fisher 1989, Huryn and Wallace 2000).

This CE does not include the Loamy Bottom Ecological Site where giant sacaton (*Sporobolus wrightii*) dominates, as described by NRCS (Wright 2002, Robinett 2005a) and Stromberg et al. (2009). Stands of giant sacaton may be adjacent to the woody riparian ecosystems or near-by within the same valley.

Figure C-29. Photos of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream in Bear Canyon (left) and Sycamore Canyon (right), Coronado National Forest

C-9.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. Sources include the Gila Ecoregion in Freshwater Ecoregions of North America (Abell et al. 2000), and Stefferud et al. (2009).

Reptiles and Amphibians: Mexican garter snake, Chiricahua Leopard Frog *(Rana chiricahuensis)*

Mollusks: Wet Canyon Talussnail, Madera Talussnail, and Cave Creek Woodlandsnail

Invertebrates: caddisflies, damselflies, and stoneflies

Birds: Gray hawk, yellow-billed cuckoo, Southwestern Willow Flycatcher (*Empidonax trailii extimus*), and many other migratory and breeding species, including Bell's Vireo, Elegant Trogon, and Western Yellow-billed Cuckoo.

Fishes: Spikedace (*Meda fulgida*) (Gila R), loach minnow (*Tiaroga cobitis*) (Gila & San Francisco R.), Gila trout (*Salmo gilae*), Long fin dace (*Agosia chrysogaster*) and Gila topminnow (*Poeciliopsis occidentalis*) endemic to Gila R., Gila chub (*Gilia intermedia*), Colorado Squawfish (*Ptychocheilus lucius*) and Razorback sucker (*Xyrauchen texanus*) endemic to Colorado River Basin may once have been in the Gila R., and Roundtail chub (*Gila robusta*) Gila R. [source: Abell et al. 2000]. Additional fishes include the Sonora sucker (*Catostomas insignis*) and the Desert Sucker (*Pantosteus clarki*) (Stefferud et al. 2009).

Mammals: Beaver (*Castor canadensis*)

Plants: Gentry's Indigo Bush, Chiricahua Mountain Alum-root, California Satintail, Southwest Monkeyflower, and Frog's-bit Buttercup.

C-9.4 Natural Dynamics

The hydrologic regime of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem is naturally highly variable temporally and spatially among the streams of this ecosystem.

Faunal and floral composition and dynamics – both terrestrial and aquatic – are shaped by episodic flooding and associated sediment scour and deposition, and by the rise and fall of the alluvial water table. Vegetation is relatively dense, especially when compared to drier washes. Bedrock formations force groundwater to the surface where it supports the shallow alluvial water table and channel baseflow (e.g., Stromberg et al. 1996, Stromberg 1998, USFWS 1999, Shafroth et al. 2000, Snyder and Williams 2000, Horton et al. 2001, Stromberg 2001, Eby et al. 2003, Calamusso 2005, Lite and Stromberg 2005, Stromberg et al. 2005, Leenhouts et al. 2006, Stromberg et al. 2006, Webb and Leake 2006, Stromberg et al. 2007, Propst et al. 2008, Katz et al. 2009, Shafroth et al. 2010).

This riparian and aquatic ecosystem has high spatial and temporal variation that is driven by many abiotic factors. The timing, duration, temperature range of flow pulses (from watershed runoff) - are shaped by the warm, arid climate with extreme contrast between daytime and nighttime temperatures. Spatial extent of perennial flow is controlled by the distribution of bedrock canyons and sills that force alluvial groundwater flow to the surface, by the distribution of buried channel gravels, and by the distribution of springs from deeper aquifers with sufficient discharge to support streamflow. The limited precipitation is concentrated at higher elevations mostly as rainfall but sometimes also as snow, and substantial precipitation and/or snowmelt events are necessary to produce surface runoff (e.g., Price et al. 2005).

The presence and magnitude of such runoff events vary greatly from season to season, year to year, and decade to decade (e.g., Price et al. 2005, Serrat-Capdevila et al. 2007). Perennial surface water flow within the Coronado NF and in surrounding watersheds appears to have declined in recent years, although there are no gauging stations to verify this. The cause of the decline is thought to be prolonged drought from 1995-2005. In addition, extraction of groundwater for land uses such as agriculture and development is lowering water tables and decreasing perennial surface water (CNF 2009).

Evaporation and riparian transpiration also consume water seasonally, contributing to losses of flow along individual stream reaches during the growing season, except during runoff flow pulses. Riparian water table dynamics follow suit: the water table rises during high-flow events and falls between such events, unless the water table is controlled primarily by an upward leakage of groundwater, forced to the surface by bedrock sills (e.g., Webb and Leake 2006).

Finally, average water temperatures are lower and concentrations of particulate organic matter are higher during runoff pulses, as are concentrations of suspended and re-suspended sediment. In contrast, average water temperatures are higher and concentrations of particulate organic matter are lower during baseflow, as are concentrations of suspended and re-suspended sediment. Riparian vegetation also can influence flow by slowing and trapping sediments (Stromberg et al. 2009).

C-9.4.1 Fire

Fire in riparian areas is less common than in surrounding uplands but does occur, as often as 5-15 times in the last 22 years, and burned from less than 1 acre up to approximately 300 acres (CNF 2009). Fire is a disturbance agent and many riparian species respond by re-sprouting after fire, if the fire was not too hot (Stromberg and Rychener 2010, Luce et al. 2012).

C-9.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque / Stream ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-9.5.1 List of Primary Change Agents

Occurrences of this ecosystem – both their riparian areas and aquatic communities – are directly affected by concentrated grazing, cutting of woody vegetation, land development, river channelization including channel dredging and bank armoring, diversion of flows, withdrawals of groundwater, wildfire suppression, exotic terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized), roadways and railways that cut through/along riparian corridors, mining, point-source and diffuse (runoff) pollution, and fragmentation by dams. Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover and through water diversions and withdrawals; or that result in point and non-point-source pollution, including from abandoned and active mines and possibly from atmospheric deposition.

C-9.5.2 Altered Dynamics

Table C-34 identifies the most likely impacts associated with each of the stressors identified. Change agents, and the specific stressors they generate, cause alteration to the Key Ecological Attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the Conservation Element, such as new rural or urban development. Other stressors such as roads and other infrastructure corridors (e.g. railroads, power lines, solar arrays, oil pumping platforms and the like) cause fragmentation in the distribution or connectivity of the Conservation Element (Debinski and Holt 2001). Irrigated agriculture, in addition to completely removing portions of a Conservation Element, can also cause downstream alteration to a riparian/stream ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects can have a double effect on aquatic CEs, as they can change the amount and timing of flow, and also can fragment the network of flow (Poff et al. 2010). Aquatic invasive species often have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in Key Ecological Attributes of Biotic Condition for riparian/stream ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful, causing alteration to functional diversity and food web structure (Calamusso et al. 2005). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure. Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling or cause changes in vegetation on stream banks that affect bank and channel stability; and changes in beaver populations can change hydrology and nutrient cycling. Figure C-30 and Figure C-31 capture these interactions, and the use of indicators to track them.

Table C-34. Stressors and their likely impacts on the North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review, of which there are many for each stressor).

Stressor	Impacts
Land Use	
Concentrated grazing	Removal of native vegetation, changes to native composition and structure, possibly favoring invasion of non-native vegetation (Patten 1998, Robinett 2005b) thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008); erosion of stream banks and channel; stream pollution (sediment, manure) (Robinett 2005c) which can be detrimental to fish habitats (Calamusso 2005).
Unregulated recreation	Elimination and fragmentation of riparian habitat; increased soil erosion; point and non-point source pollution, cutting of woody vegetation, (Debinski and Holt 2000).
Cutting of woody vegetation	Removal of native vegetation, possibly favoring invasion of non-native vegetation (Patten 1998, Stromberg et al. 2009), thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008) which can impact the amount of woody debris important for fish habitat (Calamusso 2005).
Development	
Roadways/railways	Elimination and fragmentation of riparian habitat; altered longitudinal surface flow paths in alluvial aquifer; non-point source pollution (Comer and Hak 2009).
Mining within riparian zone	Elimination and fragmentation of riparian habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; point source pollution (Mol and Ouboter 2004, Berkman and Rabeni 1987).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Webb and Leake 2006, Poff et al. 2010, Anning et al. 2009).

Stressor	Impacts
Land development	Elimination and fragmentation of riparian habitat; reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Fragmentation by dams	Fragmentation of riparian habitat and aquatic connectivity very important to fish habitat (Calamusso 2005)
Hydrologic Alterations	
River channelization	Elimination of natural geomorphic dynamics; elimination of bank and over-bank recharge to alluvial aquifer during runoff pulses; elimination of groundwater discharge along armored reaches; channel entrenchment resulting in lowered groundwater table (Noonan 2013) which degrades fish habitat (Calamusso 2005).
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, disconnect with the floodplain which can increase sediment transport and change the aquatic habitat (Calamusso 2005, Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010), causing loss to flora an faunal ecology (Patten 1998, Stromberg et al. 2007, Faber-Langendoen et al. 2008).
Point-source pollution along riparian zone	Direct alteration of surface water and potentially also groundwater quality which can lead to poor water quality detrimental to fish habitats (Luce et al. 2012, Calamusso 2005).
Point-source pollution, watershed	Alteration of water quality in flows arriving from upstream and tributaries which can lead to poor water quality detrimental to fish habitats (Luce et al. 2012, Calamusso 2005).
Non-point-source pollution	Alteration of water quality in flows arriving from upstream and tributaries as well as in surface runoff along/within the riparian zone itself (Abell et al 2000) which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table (Stromberg et al 1996, Calamusso 2005, Poff et al. 2010). Changes in flow can cause increased channel incision and down cutting of the stream bed (Noonan 2013), and cause severe habitat changes (Robinett 2005b, Falke et al. 2011).
Changes to natural Wildfire regime	Change in vegetation succession dynamics, such as the encroachment and increase density of native and non-native woody species, such as tamarisk , and hot fires that change soil characteristics (Stromberg et al. 2009, Stromberg and Rychener 2010, U.S. Fish and Wildlife Service 2002).

Stressor	Impacts
Invasive Species	
Exotic terrestrial plants and animals	Replacement of native vegetation, altering riparian habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality;, alteration of fire risk; alteration of soil and channel stability either through an increase (such as tamarisk thickets) or decrease (annuals replacing perennial graminoid species); alteration of ground-litter chemistry; alteration of evapotranspiration rates and timing (Stromberg 1998, Robinett 2005b).
Exotic aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Rinne 1996, Calamusso 2005, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

C-9.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-9.6.1 Key Ecological Attributes

Table C-35 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-35. Key Ecological Attributes (KEA) and stressors of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem.

KEA Class: Name	Definition	Rationale	Stressors
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the riparian/stream ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Surrounding watershed cover also shapes the connectivity between the riparian/stream corridor and the surrounding landscape for fauna that move between the two settings; and the longitudinal connectivity of the buffer zone alongside the corridor within which additional wildlife movement takes place. (Comer and Hak 2009)	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Development and excessive grazing also can introduce pollutants and cause fragmentation (reduces connectivity) between the riparian/stream corridor and the surrounding landscape and along the buffer zone surrounding the corridor. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Vegetation Corridor Extent**	The longitudinal extent of uninterrupted (unfragmented) native vegetation patches along the riparian corridor.	Unfragmented riparian corridors support individual animal movement, gene flow, and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend. More extensive and highly connected riparian corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance or incursions by non-native species (Faber-Langendoen et al. 2012b). Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic will not be used as a measure of health.	Stressors to vegetation corridor extent include development on/in the riparian corridor itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in vegetation corridor extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
***Size/Extent:* Aquatic Corridor Extent**	The longitudinal extent of the stream channel network, uninterrupted by barriers or reaches without even naturally seasonal or intermittent flow.	Unfragmented aquatic corridors support up- and downstream movement and gene flow for aquatic animal species, natural downstream transport of larvae and seeds, and natural downstream transport of sediment and both dissolved and suspended nutrient matter -- all processes crucial to sustaining the aquatic food web, aquatic and riparian species populations, and succession and recovery from disturbances. More extensive and highly connected aquatic corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance. Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic will not be used as a measure of health.	Stressors affecting aquatic corridor extent include dams and diversions, riparian corridor development (see Vegetation Corridor Extent), surface- and groundwater use (see Hydrologic Regime), channelization (see Geomorphology), and concentrated contamination such as from mine waste (see Water Chemistry). Climate change also has the potential to cause additional change in aquatic corridor extent, through its impacts on hydrology (see Hydrologic Regime).
***Biotic Condition:* Riparian Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the riparian corridor including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of riparian faunal assemblage is important aspects of the ecological integrity of a riparian ecosystem. Numerous native species of birds, mammals, reptiles and amphibians, and invertebrates use riparian habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to riparian vegetation composition, riparian corridor connectivity, soil moisture, and the availability of surface water. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic and functional composition of the riparian faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Riparian & Aquatic Flora**	The taxonomic composition of the native floral assemblage of the riparian corridor including woody and non-woody vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the riparian & aquatic floral assemblage is an important aspect of the ecological integrity of a riparian/aquatic ecosystem. Numerous native species of woody and non-woody plants occur preferentially or exclusively in riparian habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to riparian corridor hydrology (e.g., water table and flood dynamics), aquatic and riparian corridor connectivity (affecting availability of seed for re-colonization following disturbance), and altered water quality. Alterations in the taxonomic composition of the riparian floral assemblage beyond its natural range of variation therefore strongly indicates the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic composition of the riparian native floral assemblage experiences include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the stream, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage are important aspects of the ecological integrity of a stream ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to stream hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of surface flow in the stream channel and surface-groundwater interaction along the riparian corridor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; and the magnitude of seasonal and annual water table mean elevation.	The surface flow regime determines which aquatic species can persist in a stream system through their requirements for or tolerances of different flow conditions at different times of the year; shapes sediment transport and geomorphology and therefore aquatic habitat distributions and quality; and determines the pattern of flood disturbance. In turn, interactions between the surface flow regime and underlying aquifer conditions shape the pattern of baseflow in the former and the pattern of water table variation along the riparian corridor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and riparian habitat and biological diversity (e.g., Poff et al. 1997; Collins et al. 2006; Poff et al. 2007).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; riparian corridor development; and alterations to the riparian floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the riparian zone and across the surrounding watershed. Climate change may also cause changes in human water use.
Abiotic Condition: **Geomorphology**	The geomorphology of the stream channel, banks, and floodplain, including channel bed form, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Channel and floodplain geomorphology, shaped by watershed runoff (sediment and water) and surface flows in the stream, create the habitat template for both riparian and stream flora and fauna. Altered channel substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both stream-floodplain and surface-groundwater interactions along riparian corridors.	Stressors affecting the geomorphology of the stream channel, banks, and floodplain include the cumulative effects of alterations to watershed cover, riparian and aquatic corridor connectivity, riparian flora, and hydrology; the effects of bank and channel trampling from excessive use by livestock; and the effects of direct channel and floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in stream channel morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the water moving into the riparian corridor water table and along the stream channel, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through riparian and stream habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and stream water chemistries. Stream fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants.	Stressors affecting water quality include the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
Abiotic Condition: **Fire**	The pattern of fire occurrence (fire regime) within the riparian corridor, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in riparian vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and riparian corridor vegetation due to other factors.

C-9.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in Table C-35 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-36. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. Abiotic Condition also has stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-36. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table C-36. Relationship of Key Ecological Attributes (KEA) for the North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X		X	
Vegetation Corridor Extent		X		X
Aquatic Corridor Extent		X		X
Biotic Condition: Riparian Fauna		X		X
Biotic Condition: Riparian and Aquatic Flora		X		X
Biotic Condition: Aquatic Fauna		X		X
Abiotic Condition: Hydrologic Regime	X	X		X
Abiotic Condition: Geomorphology	X	X		X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X		X

C-9.8 Conceptual Model Diagrams

Figure C-30. Conceptual model diagram for North American Warm Desert Lower Montane Riparian Woodland & Shrubland and Aquatic Stream Ecosystem describing the structural components and functional relationships that characterize this system. Ovals represent Key Ecological Attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

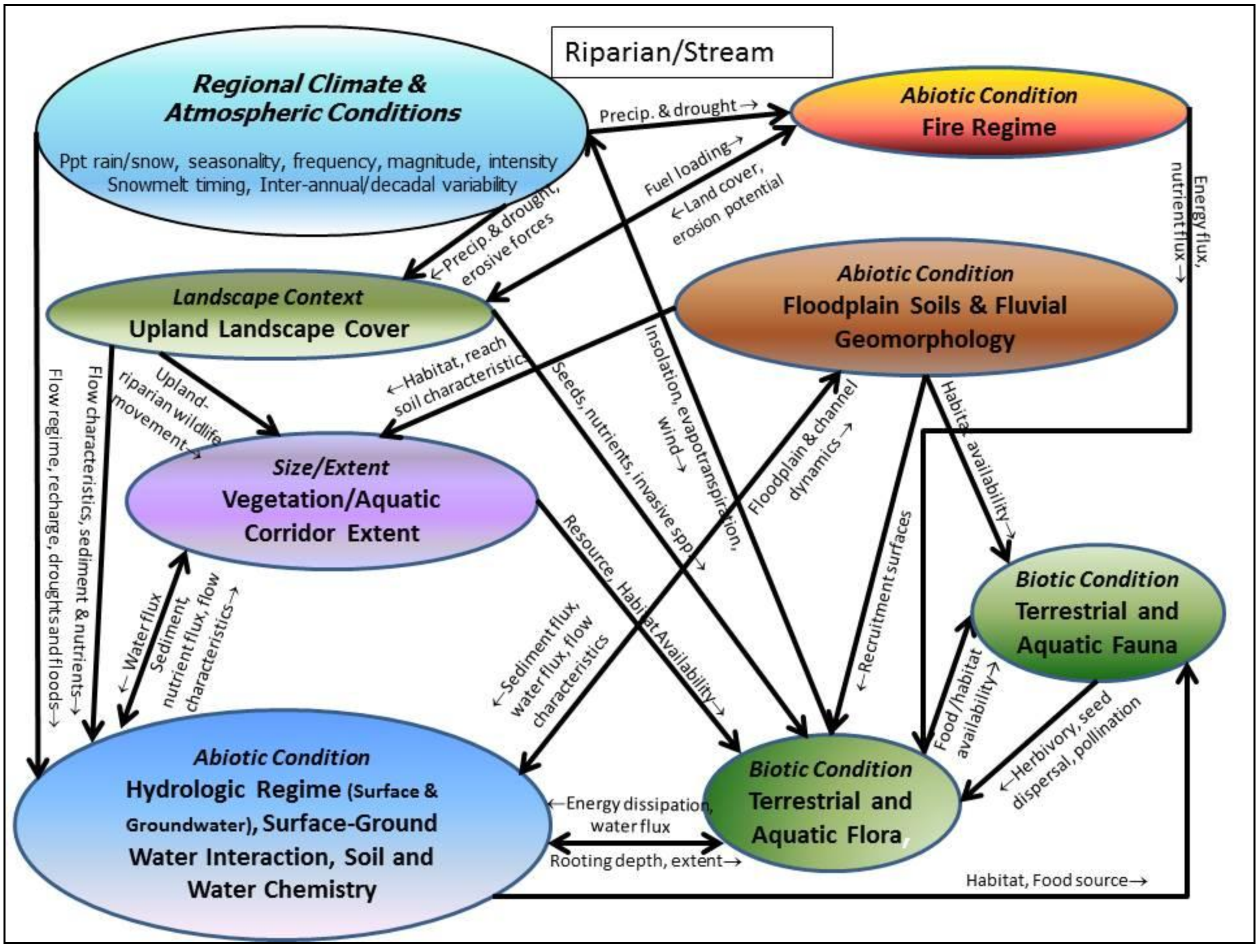
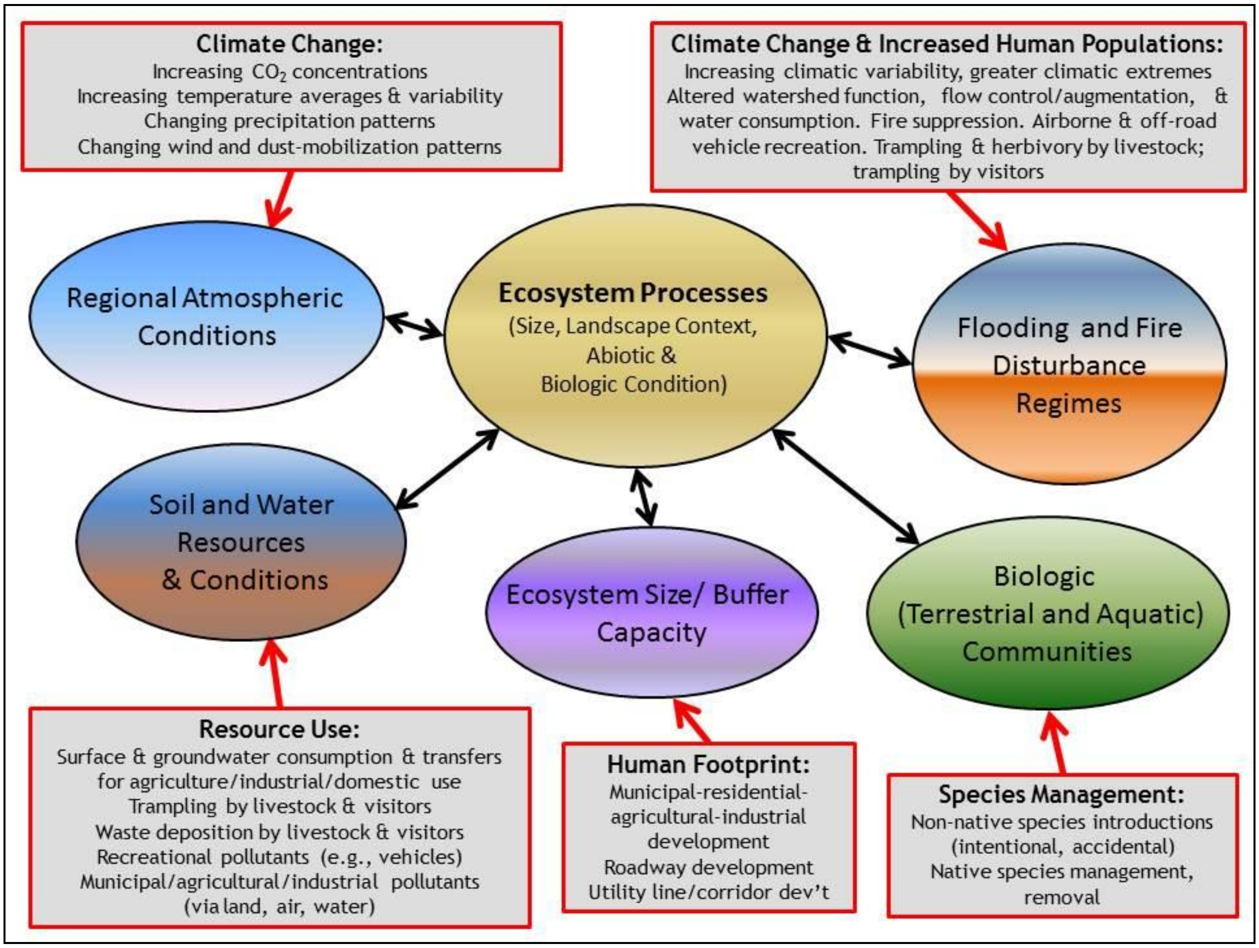


Figure C-31. Major stressors affecting riparian ecosystems' key ecological attributes.



C-9.9 References for the CE

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Isolated Wetland System

Playa Lakes

C-10 North American Warm Desert Playa/Ephemeral Lake

C-10.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- North American Warm Desert Playa (CES302.751)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)
- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)

C-10.2 Summary

This ecological system consists of barren and sparsely vegetated playas (generally < 10% plant cover) in the warm deserts of North America (Figure C-32). They form in closed, shallow drainage pockets or basins that experience intermittent flooding from surface runoff and, in some instances, from shallow groundwater discharge (e.g., Desert Processes Working Group 1991; Haukos and Smith 1992). Flooding is followed by evaporation, leaving behind a saline evaporite residue, the chemistry of which depends on the hydrochemistry of the surrounding surface runoff catchment. The flooding also carries in sediment, typically clay, silt, and fine-grained sand, which may result in stratified deposits. The evaporites commonly contain chlorides, sulfates, nitrates, carbonates, borates, or other salts, including toxic cyanates or arsenates. Salt crusts are common (Figure C-32), with small saltgrass beds in depressions and sparse shrubs around the margins. Subsoils often include an impermeable layer of clay or carbonate-cemented soil. Playa surfaces change seasonally with addition or loss of water, and with wind activity. They can be smooth to rough, wet to dry, and hard to soft, puffy, flaky, cracked, ridged, and friable; and can have hummocky relief of 1 to 2 m. Dust generation by wind erosion of fine particles is common, but playas differ in their susceptible to wind erosion. Hard, smooth, and dry playas with a high clay/low salt content seem to be more frequent at the termini of ephemeral, intermittent, and dry desert watercourses. Soft, rough, wet playas with high salt/low clay content tend to occur in depressions whose floors intersect the water table (Desert Processes Working Group 1991).

Figure C-32. Photos of Wilcox and Lordsburg Playas. Top: Wilcox Playa, AZ in a dry (left) and wetted (right) state. Lower: Lordsburg Playa, NM in a wetted (left) and dry (right) state.

North American Warm Desert Playas may have surrounding vegetation rings with distinct compositions in response to salinity. Playa plant species may include *Allenrolfea occidentalis*, *Suaeda* spp., *Distichlis spicata*, *Eleocharis palustris*, *Achnatherum spp*., *Sporobolus spp*., *Tiquilia spp*., and *Atriplex spp*. Ephemeral herbaceous species may occur in high density following episodes of wetting. Adjacent vegetation is typically Sonora-Mojave Mixed Salt Desert Scrub (CES302.749), Chihuahuan Mixed Salt Desert Scrub (CES302.017), Gulf of California Coastal Mixed Salt Desert Scrub (CES302.015), Baja California del Norte Gulf Coast Ocotillo-Limberbush-Creosotebush Desert Scrub (CES302.014), or Chihuahuan Creosotebush Desert Scrub (CES302.731).

The playas in the Madrean Archipelago ecoregion consist of Willcox (aka Wilcox) Playa in AZ and a complex of three playas near Lordsburg, NM, the middle one of which, the most frequently wetted (BLM 1993, BLM 2000a, 2000b), is known as Lordsburg Playa. All have alkaline chemistries (WWF and SIA 2007, AHW 2013) due to the geochemistry of their valleys and associated groundwater systems (e.g., Hibbs et al. 2000, Konieczki 2006, ADWR 2009). The Willcox and Lordsburg playas occupy low points in the former lakebeds of Pleistocene Lakes Cochise and Animas, respectively (Schreiber 1978, Allen 2005). The soils of these former lakebeds are predominantly clays, grading into stream fluvial deposits and beach deposits around the ancient lake margins (e.g., Brown and Schumann 1969, Schreiber 1978, Hibbs et al. 2000, Allen 2005, ADWR 2009). Wetting occurs primarily through the accumulation of runoff from the surrounding drainage catchment, combined with on-site precipitation, with the clay soils of the ancient lakebeds preventing most downward percolation and thereby producing a perched water surface. Historically high groundwater levels (potentiometric surface elevations) in the alluvial soils of the valley bottoms may also have resulted in some groundwater contributions to playa surface wetting at these locations, perhaps arising around the margins of the ancient lakebed soils (Konieczki 2006, ADWR 2009). Even where high groundwater levels did not directly contribute to historical wetting, they may have supported evapotranspiration by phreatophytes (Brown and Schumann 1969, Hibbs et al. 2000, ADWR 2009). Vegetation is extremely sparse, consisting of scattered alkalai sacaton grass (*Sporobolus airoides*), other bunchgrasses (*Sporobolus spp*.), and desert saltgrass (*Distichlis spicata*), with increasing shrub cover around the periphery consisting of saltbush (*Atriplex spp*.), mesquite (*Prosopis spp*.), and saltcedar (aka tamarisk: *Tamarix ramosissima*) (Muldavin et al. 2000; Dinerstein et al. 2001; WWF and SIA 2007; AHW 2013). Mesquite stands also occur along the ancient lake shorelines (e.g., Schreiber 1978).

The playas in the Madrean Archipelago ecoregion are ecologically distinct in three ways. First, they support a diverse and seasonally changing assemblage of birds, with winter numbers > 5,000 at Willcox Playa alone. During the winter they provide roosting and feeding habitat for large numbers of sandhill cranes and smaller numbers of water birds such as killdeer, snipe, and white-faced ibis, particularly in wet winters. The cranes migrate further north late winter, after feeding and courting in the playas. The U.S. Shorebird Conservation Plan for the Intermountain West region (Oring et al. 2005) recognizes the Willcox and Lordsburg playas as potentially important regionally for providing "… excellent shoreline mudflats for fair numbers of migrant shorebirds" but also recognizes that the sites' shorebird populations are not well documented. Shorebirds noted by MacCarter 1994 (cited in Dinerstein et al. 2001) and Oring et al. (2005) among the two playas include breeding American avocet and snowy plover; migrating black-necked stilt, American avocet, western sandpiper, least sandpiper, long-billed dowitcher, and Wilson's phalarope; and over-wintering snowy plover. MacCarter (1994, cited in Dinerstein et al. 2001) also reports long-billed curlew at Lordsburg Playa. Arizona Heritage Waters program (AHW 2013) reports that "Red-tailed hawks, northern Harriers, Harris's hawks, prairie falcons, bald and golden eagles, as well as caracaras, great horned owls, and burrowing owls" all make use of Willcox Playa during the winter; and that [t]he shrubs and trees on the periphery of the playa support migrating northern flickers, white-necked ravens, and many songbird species." Carr (1992, cited in Dinerstein et al. 2001) also reports overwintering by McCown's longspurs, savanna sparrows, American pipits, lark buntings, ferruginous hawks, and rough-legged hawks. Wings over Willcox (2013) provides a detailed sightings list from 2007 onward.

Second, the playas in this ecoregion support a rich and, in at least one respect, unique assemblage of macroinvertebrates. This assemblage consists of numerous insects that emerge to mature and reproduce following episodes of wetting, with different species emerging during the winter versus summer wet seasons. Collections at the University of Arizona catalog some 400 beetle genera from Willcox Playa, including over 100 collected by a single researcher in a single season of sampling (WWF and SIA 2007 and citations therein). Most notable of these insects are tiger beetles with specialized adaptations to the alkaline chemistry of the playa soils and their ponded waters. These include *Cicindela willistoni sulfontis*, *C. haemoragica*, and *C. nevadica citata* among 17 species of tiger beetle reported around Willcox Playa alone (Rumpp 1977; Pearson et al. 2005; WWF and SIA 2007 and citations therein). Arizona Heritage Waters (AHW 2013) reports that the tiger beetles at Willcox Playa constitute "… one of the highest concentrations [of tiger beetles] in a single small area in the United States," with 11 of the 17 species occurring "in the grass and open patches of soil near water" and the other six species occupying in drier settings. Dinerstein et al. (2001) variously state that tiger beetle site diversity at

Willcox Playa is the highest reported for any site in North America or in the world. Tiger beetles could also occur at Lordsburg Playa, but no surveys are reported for the latter playa site (WWF and SIA 2007). Dinerstein et al. (2001) also report the presence in Willcox Playa of harvester ants, *Pogonomyrmex* sp., which "…build giant mounds in the playa and may be a unique, undescribed species." The macroinvertebrate assemblage also includes numerous crustaceans – particularly branchiopods – that emerge during wet episodes (WWF and SIA 2007), as is typical of playas in the Southwest (e.g., Brostoff et al. 2010 and citations therein). These crustaceans are key food resources for water birds.

Third, the playas of the Madrean Archipelago support several rare plant species. These include the Chiricahua Mountain tansyaster (*Machaeranthera riparia*) at Willcox Playa (WWF and SIA 2007-Appendix B; AHW 2013); and Griffith's saltbush (*Atriplex griffithsii* Standl; aka *Atriplex lentiformis* var. *griffithsii* or *Atriplex torreyi* var. *griffithsii*) at Lordsburg Playa (BLM 1993; Dinerstein et al. 2001; WWF and SIA 2007).

C-10.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Birds: breeding: American avocet, snowy plover; migrating: black-necked stilt, American avocet, western sandpiper, least sandpiper, long-billed dowitcher, and Wilson's phalarope; and over-wintering snowy plover. Winter uses: Long-billed curlew, Red-tailed hawks, northern Harriers, Harris's hawks, prairie falcons, bald and golden eagles, caracaras, great horned owls, and burrowing owls, northern flickers, white-necked ravens, McCown's longspurs, savanna sparrows, American pipits, lark buntings, ferruginous hawks, and rough-legged hawks. Sandhill cranes and smaller numbers of water birds such as killdeer, snipe, and white-faced ibis.

Invertebrates and Crustaceans: 400 beetle genera, Tiger beetles, harvester ants (Pogonomyrmex spp.), Ten-lined Potato Beetles, *Leptinotarsa decemlineata)*.; numerous crustaceans – particularly branchiopods, and Tadpole Shrimp (*Triops sp*)

Plants: Chiricahua Mountain tansyaster (*Machaeranthera riparia*), Griffith's saltbush (*Atriplex griffithsii*)

Reptiles and Amphibians: Texas Horned Lizard (*Phrynosoma cornutum*), Chiricahua Leopard Frog *(Rana chiricahuensis),* Plains Leopard Frog *(Rana blairi)*.

Mammals: Javelina, mule deer

C-10.4 Natural Dynamics

The playas of the Madrean Archipelago ecoregion exhibit wide inter-annual variation in the seasonal numbers of birds using the playas, the density and diversity of macroinvertebrates present, the density and diversity of plankton on which the macroinvertebrates feed, and the plant species active. This variation in biological activity mostly depends on hydrologic conditions – how much water is present, at what time(s) of the year, over what area and to what depth. These conditions in turn depend primarily on rainfall magnitudes and timing, which are highly variable in this ecoregion. Other natural factors affecting playa hydrology include air temperature, humidity, and winds, which affect evapotranspiration rates; groundwater elevations, which affect the depth to water for phreatophytes and the potential for groundwater to contribute to wetting of the playa surface; and watershed vegetation cover, which affects runoff and infiltration rates across the surrounding catchment. The natural chemistries of the water, soils, and evaporites of the playas depend on the geochemistry of the catchment and long-term patterns of precipitation and evaporation, including during the formation of Pleistocene lakes Cochise and Animas (Brown and Schumann 1969; Schreiber 1978; Haukos and Smith 1992; Hibbs et al. 2000; Smith and Haukos 2002; Allen 2005; Konieczki 2006; WWF and SIA 2007; ADWR 2009; AHW 2013).

C-10.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Playa ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

C-10.5.1 List of Primary Change Agents

The locations in which this ecosystem occurs are determined by basin-scale topography and its geologic history. Within these locations, the spatial extent of the active area of each playa – the area across which wetting occurs – is affected both directly and indirectly by human activities. Activities that may directly alter playa ecological dynamics include the draining of playa waters to permit additional use of the exposed land, artificial regulation of water levels such as behind berms, diversion of runoff that would otherwise wet portions of a playa, and groundwater withdrawals that lower the water table; excessive grazing; and recreational use such as OHV activity (BLM 1993; BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007). Willcox Playa is partially fragmented by a railroad grade that cuts across its west-northwest extension; and Lordsburg Playa is fragmented by Interstate Highway 10 and NM State Road 338, as well as by an abandoned railroad grade that cuts across its northern half. Surface diversion and groundwater withdrawal rates are high in the catchments for both the Willcox and Lordsburg playas primarily due to irrigation farming demand but secondarily due to municipal demand (Allen 2005; Daniel B. Stephens and Associates 2005; Konieczki 2006; ADWR 2009). Arizona Electric Power Cooperative operates its coal-fired Apache Generating Station on the southwest edge of Willcox Playa; PNM Resources operates its natural gas-fired Lordsburg Generating Station and Tri-State Generation and Transmission Association operates its natural gas-fired Pyramid Generating Station in the immediate vicinity of Lordsburg Playa (NMENV 2013). All three facilities use groundwater for cooling (Daniel B. Stephens and Associates 2005; Konieczki 2006; ADWR 2009). Other activities that could <u>in</u>directly alter playa ecological dynamics – because of their potential to affect playa hydrology and water chemistry – include climate change; alterations to land cover within the catchment for a playa that alter rates of water and soil runoff; and atmospheric and ground-based pollution.

C-10.5.2 Altered Dynamics

Table C-37 identifies the most likely impacts associated with each of the stressors identified in Section 1.1.2.1. These impacts arise largely due to direct conversion of playa habitat to incompatible uses; alteration of playa hydrology; pollution; altered on-site soil disturbance; and altered sediment inputs from the surrounding valley. The cumulative effects of these impacts on the biological conditions in the playas may include changes in their patterns of use by bird species, changes in the seasonal composition of the invertebrate community, and losses of rare plant species. Changes in the viability of the playas as stopovers for migratory birds, in turn, will affect bird population sizes and their contributions to ecosystems elsewhere along their migration routes. (Changes elsewhere along their migration routes also necessarily affect bird utilization of the playas, in turn).

The cumulative effects of the stressors listed in Table C-37 impacts may also include increased wind erosion of the playa soils. Such increased erosion, in turn, can promote the formation of local dust storms and larger-scale transport of dust clouds containing playa microbes and evaporites, which may affect both people and ecosystems in the surrounding region (BLM 1998; Gilbert et al. 2009). Figure C-33 and Figure C-34 capture these interactions, and the use of indicators to track them.

Table C-37. Stressors and their likely impacts on the North American Warm Desert Playa ecosystem type in the Madrean Archipelago ecoregion.

Stressor	Impacts
On-site surface drainage (ditches)	Reduced wetted area; increased use of land for more “dry-ground” activities such as grazing (e.g., Dinerstein et al. 2001).
On-site water level regulation	Loss of natural variation in wetted area, and in timing and duration of wetting.
Runoff inflow diversion	Loss of surface inflows, with consequent reduction in wetted area (e.g., Dinerstein et al. 2001).
Groundwater withdrawal	Increased loss of playa water due to increased infiltration through soil cracks and through more porous soils around playa margins (e.g., Hibbs et al. 2000; Dinerstein et al. 2001; Konieczki 2006; WWF and SIA 2007; ADWR 2009).
On-site development, e.g., for irrigation	Reduced wetted area; altered hydrology; introduction of agricultural chemicals; altered formation of evaporites (e.g., Dinerstein et al. 2001).
Watershed development	Altered runoff; altered sediment inputs from watershed during runoff events; altered non-point source pollution.
Livestock grazing	Catchment-scale removal of native vegetation in ways that alter runoff and evapotranspiration rates; on-site removal of native vegetation and/or introduction of non-native vegetation; trampling/compaction of playa soils; on-site and catchment runoff pollution by animal wastes (e.g., BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007).
Recreation	On-site soil disturbance (e.g., BLM 1998).
Roadways/railways	Fragmentation of playa habitat; altered distribution of wetting.
Atmospheric deposition	Altered playa water and soil chemistry, such as altered pH and concentrations of S, N, and Hg.
Climate change	Altered watershed- and site-scale precipitation and evapotranspiration rates and timing, affecting magnitude, timing, and duration or wetting. Climate change may also cause changes in human consumption of surface water and groundwater.

C-10.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

C-10.6.1 Key Ecological Attributes

Table C-38 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource’s biology, ecology, or physical environment that is critical to the resource’s persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table C-38. Key ecological attributes (KEAs) of North American Warm Desert Playa ecosystem.

KEA Class: **Name**	**Definition**	**Rationale**	**Stressors**
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the playa ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the playa location from the surrounding runoff catchment. Surrounding watershed cover also shapes the connectivity between the playa and the surrounding landscape for fauna that move between the two settings (e.g., Smith and Haukos 2002; Comer and Hak 2009).	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of rainfall runoff, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the playa. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Playa Area & Connectivity**	The number, average wetted area, and fully connected area of playas (watershed and ecoregional scales) and their variation over time (seasonal, annual, longer-term).	As with the size of any wetland, the amount of playa habitat available in an area directly affects the density and diversity of playa-dependent species present and their variation over seasonal, annual, and longer-term timescales (e.g., Faber-Langendoen et al. 2008). Connectivity within a playa or set of adjacent playas - how few barriers exist that may prevent movements of water and species between adjacent areas during wet episodes - in turn may affect the relative isolation of populations of some plant and animal species that require water for transport/movement between sites.	Stressors to playa area and connectivity include all factors potentially affecting the hydrology of the playas (see Hydrologic Regime), as well as direct conversion of playa habitat to other uses (e.g., for irrigated farming) and imposition of barriers to the distribution of surface water such as road/railroad grades.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Bird Use**	The taxonomic composition and size of the bird community that assembles at the playas; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition and size of the bird community using the playas are important aspects of the ecological integrity of the ecosystem. Numerous native species of birds use the playas in this ecoregion for feeding, resting, and breeding, either as home bases or as stopovers or end-points in their annual movements; and the birds community composition and size naturally vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to wetted area and water quality that affect the availability of both physical habitat and food (e.g., Haukos and Smith 1992; BLM 1993; BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007; AHW 2013). Alterations in the taxonomic composition and size of the playa bird community beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors to the taxonomic composition and size of the bird community using the playas include the cumulative impacts of all stressors affecting the landscape context, size/extent, invertebrate community composition, vegetation, and abiotic condition of the playa ecosystem; the cumulative effects of all stressors affecting the natural visitors in other parts of their annual ranges of movement; excessive hunting; disturbance during breeding; and incursions of non-native species that may compete with or prey on the native avifauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Invertebrates**	The taxonomic composition and biomass of the macroinvertebrate community that emerges in the playas during episodes of wetting; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition and biomass of the playa macroinvertebrate community are important aspects of the ecological integrity of the ecosystem. The species native to these playas possess unique adaptations to the hydrology and chemistry of these environments. Numerous specialized native species of insects and crustaceans live and reproduce in the playas in this ecoregion, persisting as eggs or dormant life-forms during dry periods; and the composition and biomass of this community naturally vary over time (seasonal, annual, longer-term). The composition and biomass of this community vary in their sensitivity to different stresses such as alterations to the extent, duration, and timing of wet versus dry conditions; and the chemistry of the water during wet episodes (e.g., Haukos and Smith 1992; BLM 1993; BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007; AHW 2013). Alterations in the taxonomic composition and biomass of the playa insect and crustacean community beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors affecting the taxonomic composition and productivity (biomass) of the playa macroinvertebrate community include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the playa ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native macroinvertebrates.

KEA Class: **Name**	**Definition**	**Rationale**	**Stressors**
Biotic Condition: **Plants**	The taxonomic composition and coverage density of the native floral assemblage of the playas including woody and non-woody vegetation; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the playa vegetation community is an important aspect of the ecological integrity of the ecosystem. The plant species native to these playas possess unique adaptations to the hydrology and soil/water chemistry of these environments. Several rare native plant species live and reproduce in the playas in this ecoregion, varying in their requirements for/tolerances of different frequencies of wetting, soil/water pH, and concentrations of nutrients and salts. The composition of this community varies in its sensitivity to different stresses such as alterations to the extent, duration, and timing of wet versus dry conditions; and the chemistry of the water during wet episodes (e.g., Haukos and Smith 1992; BLM 1993; BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007; AHW 2013). Alterations in the composition of the playa vegetation community beyond its natural range of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors to the taxonomic composition of the playa vegetation community include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including excessive grazing and OHV activity; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of variation in the area, timing, and duration of wetting of the playas over time (seasonal, annual, longer-term).	The pattern of variation in the area, timing, and duration of wetting of the playas over time (seasonal, annual, longer-term) is one of the two most important factors (see also Water Chemistry) shaping what native plant and animal species occur in the playas, how often they occur, when they occur by season, and for how long they remain present or absent (Haukos and Smith 1992).	Stressors affecting the hydrology of the playas include watershed development that alters runoff and evapotranspiration rates; surface water diversions; groundwater withdrawals that affect aquifer water elevations (aka “potentiometric surface elevation”) beneath the playas; impoundment and artificial regulation of playa water areas and depths; drainage of playa areas through ditching; and alterations to the playa and adjacent plant communities including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on rainfall spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the playas and across the surrounding watershed. Climate change may also cause changes in human water use, leading to changes in diversions and groundwater withdrawals.
Abiotic Condition: **Soils**	The condition of the playa soils, as characterized by their particle size ranges, and by their disturbance/erosion and fracturing patterns during drying cycles.	The particle size ranges of the playa soils, and the patterns of disturbance/erosion and fracturing of these soils during drying cycles, determine the permeability of these soils and the ability of macroinvertebrate eggs and dormant life forms to persist during dry periods; and therefore directly affect playa hydrology and biological condition (Haukos and Smith 1992).	Stressors affecting the particle size ranges of the playa soils, and the patterns of disturbance/erosion and fracturing of these soils during drying cycles include: changes to the transport of sediment from the watershed out onto the playa itself caused by changes in watershed soil erosion and runoff rates and in surface drainage flow paths (see Landscape Cover; Hydrologic Regime); and human activities directly on the playa soils, such as excessive grazing and vehicular activity, that disturb playa soil structure through compaction and disaggregation.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the playa water during wet periods, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water that fills the playas during wet episodes strongly determine which plant and animal species can persist in this habitat, as determined by their requirements for/tolerances of different ranges of soil/water pH, and concentrations of nutrients and salts. The pattern of variation in pH and concentrations of nutrients and salts in playa waters during wet episodes over time (seasonal, annual, longer-term) is the other dominant factor (see also Hydrologic Regime) shaping what native plant and animal species occur in the playas, how often they occur, when they occur by season, and for how long they remain present or absent (Haukos and Smith 1992).	Stressors affecting playa water chemistry include the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., wastewater), atmospheric deposition, and excessive use of playa zones as pasturing areas for livestock. Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.

C-10.7 Conceptual Model Diagrams

Figure C-33. Conceptual model diagram for North American Playa/Ephemeral Lake Ecosystem. This model outlines the key structural components and functional relationships that characterize this system. Ovals represent Key Ecological Attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

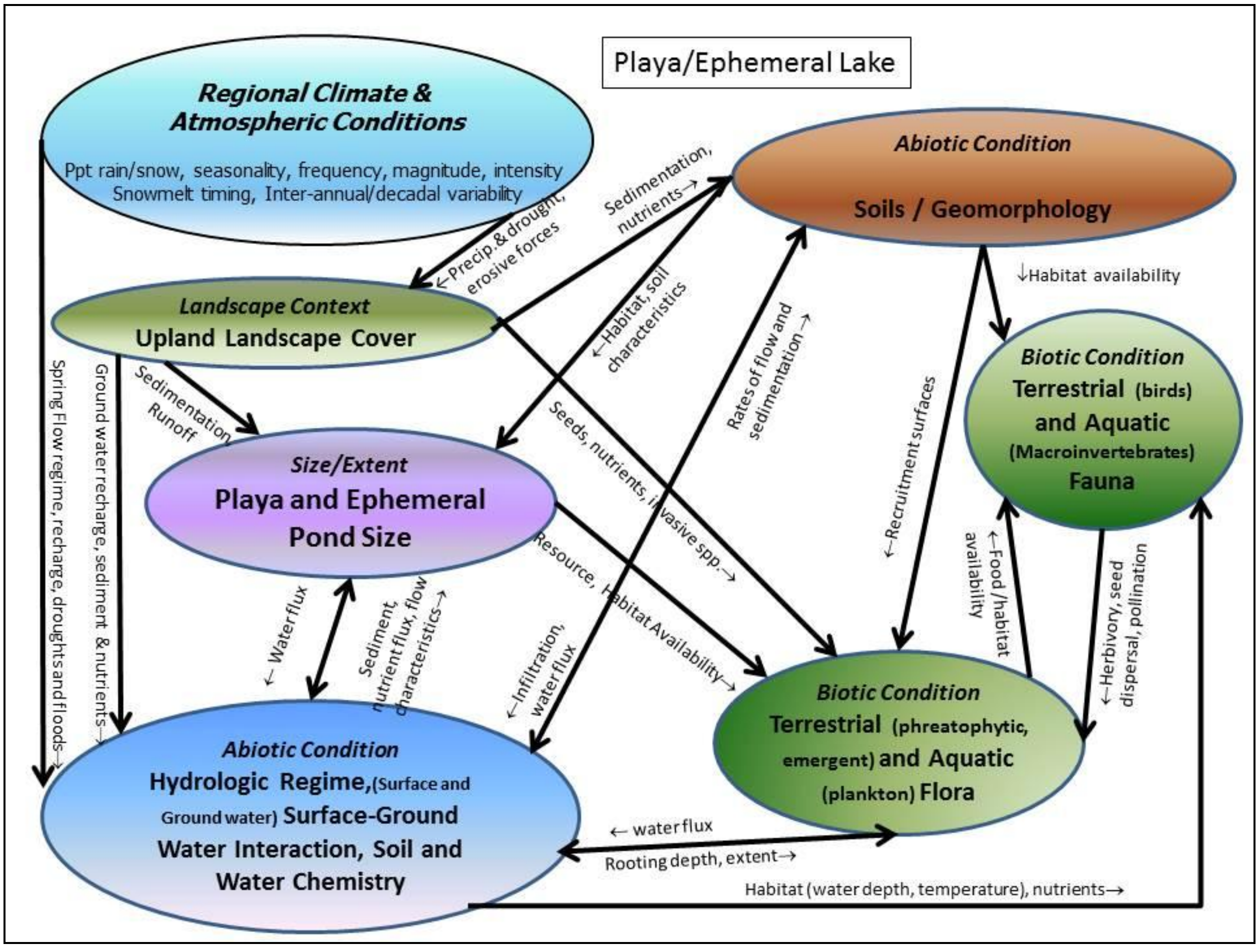
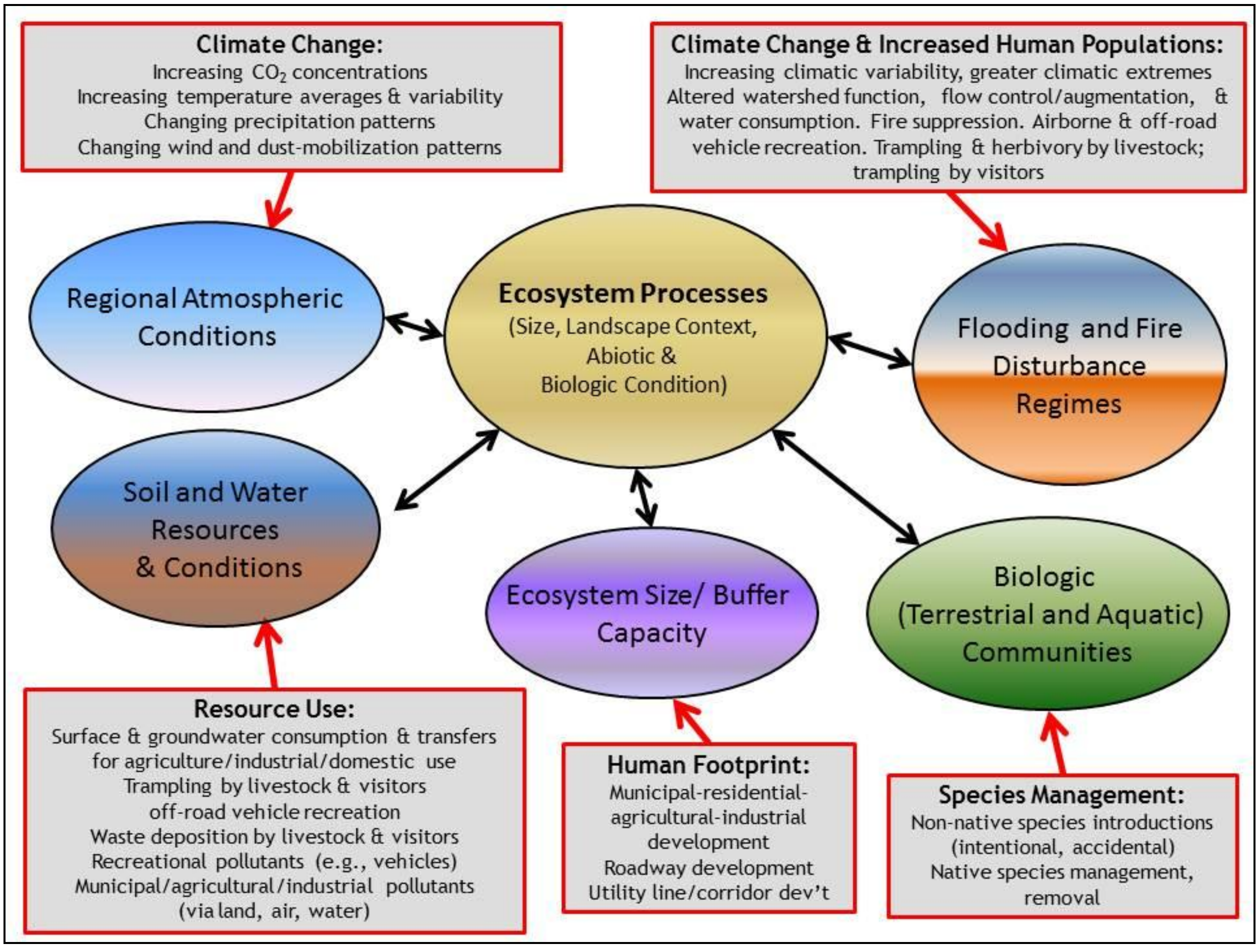


Figure C-34. Some of the greatest stressors affecting Madrean Playa Ecosystem Key Ecological Attributes.



C-10.8 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in Table C-38 also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in Table C-39. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. Abiotic Condition also has stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in Table C-39. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table C-39. Relationship of Key Ecological Attributes (KEAs) for the North American Warm Desert Playa ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X			
Playa Area & Connectivity		X		X
Bird Use		X		X
Invertebrates		X		X
Plants		X		X
Hydrologic Regime	X	X		X
Soils	X	X		X
Water Chemistry	X		X	

C-10.9 References for the CE

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